DISSERTATION

PREDATORS OF JWANA GAME PARK, BOTSWANA - A POTENTIAL SOURCE OF CONFLICT WITH LOCAL HUMAN COMMUNITIES

by

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Declaration

I declare that ***'Predators of Jwana Game Park, Botswana - A potential source of conflict with local human communities'*** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to originality checking software and that is falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at UNISA for another qualification or at any other higher education institution.

Student Signature______________________ **Date** **19-08-2019**

ABSTRACT

Human-wildlife conflict continues to grow as a concern across the world. The conflict is experienced in many different forms and it has become persistent on the pastoral lands that are situated closer to the boundaries of protected areas with livestock predation being the most prevalent form of conflict. The type and severity of the conflict is largely dependent on the predator involved and the efficiency of the mitigation techniques employed. In an attempt to minimise human-wildlife interactions, many countries have set aside pieces of land for biodiversity conservation and management of wildlife species. However, the majority of these protected areas are too small to meet the ecological requirements of resident medium-large predator species. This results in some species dispersing into the neighbouring unprotected land where they come into contact with domestic animals, killing them and sometimes causing injuries. These livestock attacks ultimately trigger indiscriminate killing of predators that is fuelled by economic losses that are accrued through livestock predation and communities' negative perceptions towards predators.

Camera trapping and spoor count techniques were used to study the occupancy of medium-large predator species and their movement in and out of Jwana Game Park through the holes that occur under the park's perimeter fence. In addition, a questionnaire survey was conducted in the cattle posts that are situated adjacent to Jwana Game Park. Seven medium-large predator species were detected within the boundaries of the park. Occupancy estimates varied among the predator species within the different sections of the game park. Predators also exhibited movement between the park and adjacent pastoral land using holes that occurred under the park's boundary fence. A total of 128 active holes were recorded under the park's perimeter fence with the

majority (62%) of the intensively used holes occurring in the south-west section of the park. A total of 185 predator images were recorded at the various holes under the boundary fence with black-backed jackal (*Canis mesomelas)* constituting the majority (45%) of capture events. Human wildlife conflict is common on the neighbouring farmlands and jackal was perceived to be responsible for the majority of the livestock depredation incidents of small stock (mainly goats), whereas leopard was perceived as the most problematic predator species on the commercial cattle ranches where it accounted for 63% of livestock losses. There was no association between the occupancy of predators inside the park and the use of holes that occur under the park's the boundary fence. Conflict mitigation techniques were not efficiently practiced by communities farming in the vicinity of the game park, which potentially contributed to increased livestock attacks. The incapability of the boundary fence to restrict animal movement could also contribute to increased unwanted predator-livestock interactions.

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CHAPTER 1

General Introduction

1.1 Background of the study

Human Wildlife Conflict (HWC) is a growing concern across the globe (Nyhus *et al*. 2005; Gandigwa *et al*. 2012). The conflict generally occurs as a result of persisting interactions between humans and wildlife that ends up affecting both parties (Madden 2006; Messmer 2009). The negative impacts that go along with this interaction undermine the efforts of wildlife conservation and sustainable natural resource utilization (Gusset *et al*. 2009), ultimately threatening wildlife populations and impacting negatively on people and their property (Edge *et al*. 1990). The impacts are even more significant for species with low population densities (Cardillo *et al*. 2004). Some governments try to put initiatives such as Community Based Natural Resource Management (CBNRM) (Du Toit 2002) and compensation schemes (Nyhus 2016) in place to cushion the impacts of wildlife on affected local communities. However, negativity attached to these socio-ecological interactions outweigh the potential benefits of these initiatives, thus reducing the perceived worth of natural resources in rural community development (Sillero-Zubiri & Laurenson 2001; Frank *et al*. 2005; Patterson *et al*. 2004; Gusset *et al*. 2009; Messmer 2009). Human-wildlife conflict is experienced in various ways. Examples include livestock depredation and crop raiding (Benka 2012), attacking and sometimes killing people (Hanks 2006; Woodroffe *et al*. 2007; Datta-Roy *et al*. 2009) and transmitting diseases to domestic animals (Benka 2012). The gradual escalation of this conflict is attributed to a number of factors such as habitat loss and fragmentation, prey population decline, poor land use planning and ever-increasing human populations, and intrusion of wildlife in human dominated landscapes (Madden 2006; Baker *et al*. 2008)

Although predators play a significant role in the overall functionality and integrity of natural ecosystems (Soule & Terborgh 1999), they are often considered key players in the conflict between wildlife and livestock owners (Hemson 2003; Patterson *et al*. 2004). Reports of predators killing livestock have instilled anger and encouraged indiscriminate killings of predators by people (Treves & Karanth 2003). Often, this fuelled by the severity of economic losses that are experienced by livestock owners when they lose livestock (Ogada *et al.* 2003).

A number of conflict mitigation techniques have been tested and implemented in farming areas across the world, with their effectiveness varying from one area to another depending on the kind and/or severity of conflict (Bauer & Kari 2001; Marker *et al*. 2005; Woodroffe *et al*. 2007), wildlife species involved and uptake rate by farmers (Woodroffe *et al*. 2005; Woodroffe & Frank 2005). Efficient livestock management has been found to minimise the damage and still be consistent with sustainable livestock production (Edge *et al*. 1990). This process requires a more integrated approach of combining good livestock husbandry with effective predator control methods. Various traditional mitigation methods have been used across Africa and include construction of predator-proof kraals, kraaling livestock particularly at night, active livestock herding, use of livestock guarding animals such as dogs and lethal control (Ogada *et al*. 2003; Treves & Karanth 2003; Moruthi 2005).

Many countries have designated land for the protection of wildlife even though most of these protected areas are too small to support wide ranging predator populations (Kissui 2008) especially where interspecies competition is prevalent (Marker & Dickman 2005; Woodroffe & Frank *et al*. 2005). A lack of suitable space compromise the ability of large predators to maintain viable populations and this often results in the dispersal of less competitive species such as cheetah (*Acinonyx jubatus*) into unprotected land outside of protected areas which are often used by farmers as pastoral land for their livestock (Kent & Hill 2013).

Botswana is largely dominated by agricultural landscapes. It is in these areas where HWC has reached significantly high levels that require interventions from both government and non-government organizations. While the country retains significant areas of protected land (Lawson & Mafela 1990; Twyman 2001; Mbaiwa 2015), predators still move out of these protected areas in response to various ecological factors and end up impacting people, livestock and infrastructure in adjacent farmlands (Woodroffe 2000; Selebatso *et al*. 2008)

1.1.1 Theoretical and Conceptual Frameworks

Game proof fences are commonly used across many protected areas to mitigate human-wildlife conflict (Hayward & Kerley 2009; Ferguson & Hanks 2012; Kesch *et al*. 2015). The effectiveness of such fences depends on a number of factors such as type of fence, species being enclosed and the cost of maintenance (Kesch *et al.* 2014, Kesch *et al*. 2015). The soil type where a fence is located and the digging ability of predator and other species also influence the effectiveness of a fence (Kesch *et al*. 2014). As such, having knowledge of the digging species and their behaviour is crucial in developing fence maintenance plans in protected areas (Kesch *et al*. 2014).

Not all of the predators that use fence holes are primary diggers, however, large predators such as lions (*Panthera leo*), brown hyena (*Hyaena brunnea*), cheetah, caracal (*Caracal caracal*) and wild dogs (*Lycaon pictus*) are mostly opportunistic and have the ability to increase the size of holes that were originally dug by primary diggers such as jackals (*Canis mesomelas*), warthogs (*Pacochoerus africanus*), honey badgers (*Mellivora capensis*) and porcupines (*Hystrix africaeaustralis*), thus allowingthem to pass through to the other side (Kesch *et al*, 2014; Kesch *et al*. 2015). When the maintenance of a protected area's boundary fence is not efficient, the permeability of the fence is increased thus potentially resulting in increased livestock predation incidences on adjacent farm lands (Funston 2001). Regular movements of predators between protected areas and adjacent farmlands often results in frequent livestock predation (Funston 2001, Kesch *et al*. 2014). A diagrammatical representation of the conceptual framework for this study is presented in Figure1.1.

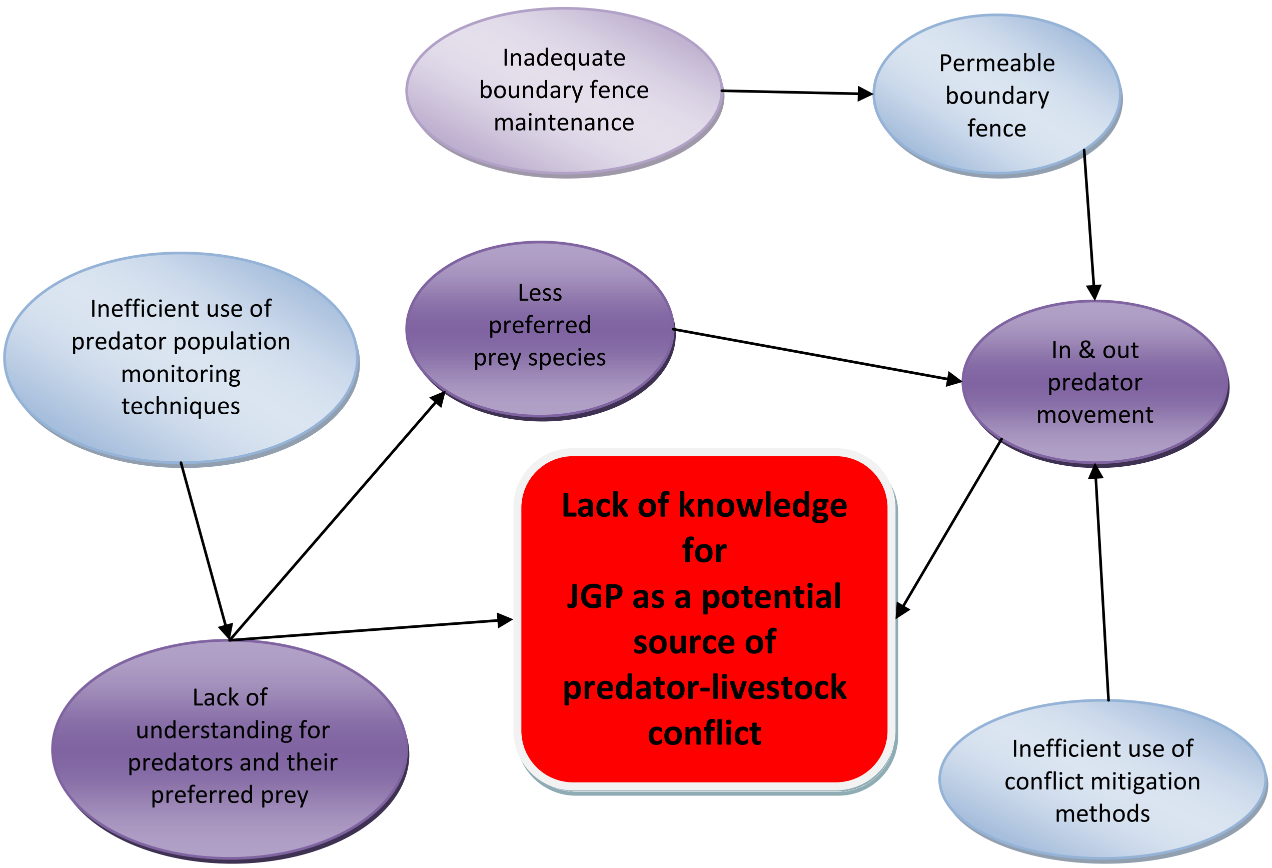

Figure 1.1 Conceptual Framework of study of predators as a source of predator-livestock conflict in Jwana Game Park

1.2 Problem Statement

Jwana Game Park (hereafter referred to as JGP) is situated in the midst of communal farmlands and cattle ranches (Houser 2008). Various predator species such as leopard (*Panthera pardus*), cheetah, jackal, brown hyena and caracal occur on JGP and are able to move in and out of the park through holes underneath the park's boundary fence (Houser 2008; Boast *et al*. 2011). Livestock depredation incidents are frequently reported by the local people farming in the areas surrounding JGP. Although it is unconfirmed as to whether individuals engaging in these depredation incidents are natural inhabitants of the pastoral lands or predators that reside inside the park and move into the farming areas, local farmers in these areas believe that predators killing their livestock come from JGP. Despite management of JGP knowing which large predator species occur within the park, monitoring of predator populations and their trends has not been efficient. The management of JGP conducts annual game censuses using aerial counts and the results show extremely low predator counts, with only one brown hyena counted in 2011, one jackal in 2012, and one leopard in 2012 (Vet & Agric Consultants 2012). These results are not surprising considering the limitations of aerial counts in monitoring predator populations as predators occur in low densities and are often elusive and nocturnal (Linnel *et al*. 1998; Durant *et al.* 2011). Other than aerial counts, no other methods are used specifically to monitor predator populations.

Despite authorities receiving continuous livestock depredation reports and allegations that the park is the cause of livestock losses to farmers in the communities adjacent to JGP, limited information is available on the potential impact of JGP on the farming communities. Whether real or perceived, these allegations substantiate the need to investigate the possibility that predators within JGP do leave the park and predate on livestock. Camera traps were used to survey medium-large predator species inside the park. The presence or absence of predators was modeled into an occupancy framework using detection probabilities. Spoor counts were also used to complement camera traps in studying presence-absence of the park's small-medium predators in relation to different habitats. The parks boundary fence was surveyed to identify and map the holes that exist underneath while rating their significance based on the intensity of use by wild animals.

The general objective of this study was to investigate predator occupancy and permeability of the JGP fence as potential contributors to human-predator conflict that prevails in communities living on the neighboring farmlands. This general objective was met by addressing the following specific objectives:

1. To investigate occupancy of medium-large predators and determine if they moved between the park and adjacent farmlands.
2. To evaluate community perceptions on predator-livestock conflict status and their use of conflict mitigation techniques.

Various methods were used in the dissertation chapters to examine these specific objectives. I used camera traps to investigate occupancy estimates of medium-large predators in the park. The method was supplemented by spoor counts technique to further establish presence-absence of various predators. Species habitat preference was assessed based on abundance of spoor for each predator species in relation to available habitats outlined by Smith *et al*. (2007). Permeability of the park's boundary fence was also assessed to establish if it allowed predators to move between the park and adjacent farmlands. Lastly, questionnaire based surveys were used to investigate community perceptions and assess their use of different conflict mitigation methods to address livestock depredation. To avoid repetition, these methods are detailed further in specific chapters of this dissertation.

CHAPTER 2

Literature Review

2.1 Managing Human-Wildlife Conflict

Human-wildlife conflict is a complex subject that emerges from a combination of socio-economic, ecological and political activities. Disputes between government and communities result from the latter's loss of economic gains brought about by depredation of their livestock by wild animals which are protected by government (Anthony *et al*. 2010). The starting point for the resolution of this conflict is the engagement of the rural communities in effective implementation of conflict mitigation methods that facilitates co-existence (Treves *et al*. 2006; Redpath *et al*. 2013). Treves *et al*. (2006) further emphasises that sustainable conflict resolution should not address biodiversity protection by compromising the welfare of affected rural communities because the survival of any damage causing animal species depends on the attitude of those communities. Some conflict mitigation methods that are commonly employed by governments and communities to reduce the impact of human-wildlife conflict are discussed below.

2.1.1 Community-Based Natural Resource Management

The concept of Community Based Natural Resource Management (CBNRM) was introduced in Africa in the 1980s (Roe *et al*. 2000) and has become an important conservation strategy (Bowler *et al*. 2010) which has since received widespread international attention (Child 1996; Leach *et al*. 1999, Dodman & Mitlin 2013; Pienaar *et al*. 2013, Pailler *et al*. 2015). The CBNRM programmes advocate for the development of policies that promote shared responsibilities on the management of natural resources by central and local governments, non-government organizations (NGOs), civil organizations and most importantly local communities (Balland & Plateau 1996). Local communities are often cognisant of local ecological processes as well as available traditional means of effectively managing their local natural resources. CBNRM programmes therefore advocate that local communities have substantial influence on the sustainable use and protection of natural resources within their localities (Brosius *et al*. 1998). For this reason, CBNRM can only be effective through the involvement and participation of all stakeholders, which calls for the identification of locally driven ideologies that propagate increased engagement of local communities (Persha *et al*. 2011; Musavengane & Simatele 2016). Previous studies have suggested that many conservation authorities involve local communities in natural resource management primarily for the purpose of protecting biodiversity and habitat integrity but often fail to expand the benefits towards development of affected local communities (Durning 1992; McNeely 1995; Dressler *et al*. 2010). Some recent studies have however observed an improvement in that regard where CBNRM as an initiative has been found to equitably attain its objectives of conserving biodiversity while improving rural community livelihoods (Mbaiwa 2015). In general, the fundamental theory behind the CBNRM initiative is to return the benefits derived from natural resources to rural communities in order to motivate them to take part in the protection of wildlife outside protected areas (Lund 2007; O'Connel-Rodwell *et al*. 2000). The CBNRM initiative should thus be motivated by the notion that active community participation in natural resource conservation can only be earned if the cost of their involvement does not exceed the benefits derived in the conservation process (Balland & Plateau 1996).

Measuring the benefits of CBNRM on local human communities is generally challenging (Pailler *et al*. 2015) due to both the variation in conservation activity locations (Sims 2010) and the communities involved (Pailler *et al*. 2015). According to Bowler *et al*. (2010), communities that are already doing well in natural resource management stand a better chance of receiving funding in support of their CBNRM initiatives. In addition, CBNRM programs often target communities that are affected by poverty (Adam *et al*. 2008).

Like many other African countries, Botswana adopted the CBNRM idea in the late 1980s. The aim of Botswana's CBNRM initiative was to foster rural community economic development and management of local natural resources (Dikobe & Thakadu 1997; Mbaiwa 2004), taking into consideration the cost implications (including conflict with wild animals) of communities who live closer to these natural resources. This CBNRM programme was then encompassed into the Wildlife Conservation Policy of 1986 and the Tourism Policy of 1990 (Mbaiwa 1999) in a bid to enhance improved local community benefits from existing natural resources. The first community-based organization (CBO) was registered in 1993 (Thakadu 2005), and over the next 10 years a further 82 CBO's were established (Madzwamuse 2004). Generally, local communities in Botswana exhibit some positive attitudes towards wildlife probably as a result of the existing programs such as the CBNRM (Mbaiwa 2004). The benefits that are associated with CBNRM amongst communities include revenue sharing as well as direct employment opportunities (Sifuna 2009). In addition, communities are now better positioned to relate natural resource abundance with tourism-based income generation and this assists communities to develop ownership towards conservation of the available natural resources (Mbaiwa 2015).

According to the Botswana CBNRM Policy of 2007, different communities across the country benefit significantly on the use of wildlife and natural resources. These prospects are supported by the findings from Thakadu (2005) and Mbaiwa (2004) who found positive natural resource conservation interest in communities who benefitted from CBNRM initiatives. In spite of the positive uptake of the CBNRM initiative, recent studies such as that of Mbaiwa (2015) have demonstrated that some CBNRM projects in Botswana have had various levels of success in both biodiversity conservation and rural community livelihood improvements. While it is safe to assume that communities in Botswana do benefit positively from natural resources, it is necessary to validate these benefits and examine the economic importance of CBNRM activities at both household and community level.

2.1.2 Compensation

Human-wildlife conflict is characterized by significant economic costs that are often experienced by rural communities who are located closer to protected areas (Distefano 2004). The best approach to deal with this conflict is to eliminate its initial occurrence (Treves & Karanth 2003), but due to the complexities that surround this issue, there is need for innovation and application of alternative mitigation strategies whether lethal (Sillero-Zubiri & Lurenson 2001) or non-lethal (Reidinger & Miller 2013). One approach for promoting possible human-wildlife interaction is to ease the negative impacts of the conflict through provision of economic incentives such as financial payments, licences to use natural resources, allowing for hunting of game or collection of fire wood, timber or fodder from protected areas thus increasing tolerance by the affected communities (Wagner *et al*. 1997; Distefano 2004). The expected results of increased tolerance would be decreased retaliatory killings of wildlife (Bulte & Rondeau 2005; Woodroffe *et al*.

2005). Retaliatory killings are mostly indiscriminate as these killings are often committed out of anger and sometimes using inhumane and/or illegal techniques such as poison and snares (Sifuna 2005), which are seldom successful in eliminating the problem (Olsen 1991; Sifuna 2009).

In wildlife compensation schemes, individual farmers who suffer loss of livestock, crops, property or sometimes human lives to wild animals are reimbursed either through monetary disbursement or replacement of the damaged property (Nyhus *et al*. 2005). The rate of compensation varies from one entity or country to another and it is often paid in relation to the market value of the damaged property (Nyhus *et al*. 2005). In some countries such as Italy, the entitlement of compensation is dependent on the membership and payment of premiums towards the insurance of the property that is susceptible to wildlife damage (Marino *et al.* 2016). In such instances strict measures are put in place to ensure that farmers adhere to the required standards of conflict mitigation methods set by the compensation agency (Nyhus *et al*. 2005). According to Wagner *et al.* (1997), the compensation scheme is administered for the purpose of managing the damage causing animal and/or its habitat, modifying human activities and increasing human tolerance. However, if not carefully implemented, compensation can result in misuse of conservation resources where farmers claim for more damage and/or losses than has actually occurred (Treves & Karanth 2003; Dickman 2010) and this behaviour ultimately promotes tension amongst communities thus compromising the efforts of attaining the primary goal of discouraging retaliatory killings (Bulte & Rondeau 2005; Sifuna 2009). The effectiveness of a compensation scheme in promoting community tolerance to wildlife differs between areas and species with the level of tolerance often being defined by the amount of damage caused by the species in question (Sekhar 1998). For example, people who lose crops adjacent to Sariska Tiger

Reserve in India show more tolerance to nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennetti*) and black buck (*Antilope cervicapra*) as opposed to wild pigs (*Sus scorfa*) and elephants (*Elephas maximus*) (Sekhar 1998) because of the difference in the significance of damage they cause (Karanth & Nepal 2012).

Although compensation is an appealing approach for dealing with human-wildlife conflict within communities, its efficiency still remains questionable (Nyhus *et al*. 2003). Bulte & Rondeau (2005) argue that, the establishment of compensation schemes holds the potential to influence communities to refrain from implementing effective farming practices knowing that any losses incurred would otherwise still be covered. In addition, the initiative might result in people moving to rural communities where they can take advantage of compensations being paid (Bulte & Rondeau 2005).

In Botswana, a compensation policy was established in response to the growing human-wildlife conflict to offset the effects of wildlife damage on human property (Mmopelwa & Mpolokeng 2008). The compensation policy is administered by the Problem Animal Control (PAC) unit under the Department of Wildlife and National Parks which has been granted the responsibility to protect wildlife, humans and property against damage caused by wildlife (Mmopelwa & Mpolokeng 2008). Compensation is limited to damage caused by seven wildlife species defined in the Policy as either being dangerous to communities or classified as highly endangered and includes lion, leopard, cheetah, wild dog, elephant (*Loxodonta africana*), crocodile (*Crocodylus niloticus*) and hippopotamus (*Hippopotamus amphibious*) (Mmopelwa & Mpolokeng 2008). However, despite this intervention, communities deem the compensation initiative in Botswana ineffective, arguing that compensation values do not match the costs incurred from wildlife damage on their livestock and other property as compensation values are calculated at only 35% of the animal's market value (Mmopelwa & Mpolokeng 2008; Kgathi *et al*. 2012).

2.1.3 Traditional methods

Livestock loss and crop damage by wildlife is a common cause of conflict between local communities, conservation authorities and wild animals. Historically, the management of this conflict relied on various mitigation techniques both lethal such as regulated hunting (Basi *et al*. 2007), and non-lethal where the problem causing animal was identified and removed from the farmlands, mostly through government intervention (Baker *et al*. 2008, Gurung *et al*. 2008). However, the gradual increase in human-wildlife conflict and the resultant impacts thereof, have forced communities to seek alternative practical mitigation strategies while still being able to promote co-existence with wildlife (Woodroffe *et al*. 2007). In Africa various traditional conflict mitigation practices have been used by livestock owners to minimize livestock depredation without the need for physical elimination of the damage causing animals (Woodroffe *et al*. 2007; Marker 1999). These methods include herding, livestock guarding dogs and the use of physical deterrents all of which are discussed below.

2.1.3.1 Active livestock herding

The custom of using herders to safeguard grazing livestock during the day has been in practice since ancient times (Woodroffe *et al*. 2007). Livestock herding plays a significant role in reducing livestock depredation (Kruuk 1980; Ogada *et al*. 2003; Woodrofe *et al*. 2006; Woodroffe *et al*. 2007) but requires a constant presence of humans accompanying the livestock when livestock is released to graze (Linnell *et al*. 1996). Effective herding of livestock allows for the avoidance of predator hot spots as well as quick and flexible responses to predator attacks, and for timely detection of sick animals that may be easy victims to predation (Woodroffe *et al*. 2007). Additional advantages of livestock herding are the quick detection and recovery of livestock that have wandered from the main herd (Mwebi 2007) as well as the reduced probability of theft (Frank *et al.* 2005).

According to Mwebi (2007) and Lyamuya *et al*. (2016), herding should preferably be done by men as opposed to women and children particularly in areas where the conflict and density of large predators is high, or in situations where livestock have to travel long distances to access good pasture. In Tanzania, livestock attack reports were significantly more frequent when women herded livestock than when men did and was attributed to natural strength differences between the bodies of men and women (Lyamoya *et al*. 2016). Generally, effective herders are able to scare away predators that are deemed dangerous like lions using simple weapons such as spears and knives (Patterson *et al*. 2004). In Northern Kenya, livestock herding coupled with the increased number of family members was positively correlated with a decline in large predator livestock attacks (Ogada *et al*. 2003). Increased number of family members in many households results in increased human presence and activity that often deters predators (Ogada *et al*. 2003). The effectiveness of livestock herding can however, be compromised under certain circumstances such as when different livestock guilds being herded together differ in speed and feeding habits (Mwebi 2007), when livestock is grazed in densely bushed areas or when livestock herds are too large (Wodroffe *et al*. 2007; Lyamoya *et al*. 2016).

2.1.3.2 Use of livestock guarding dogs

The use of livestock guarding dogs has been in practice for over 6000 years (Rigg 2001). This method involves raising a dog with a herd of livestock to establish a social bond between them (Lorenz & Coppinger 2002). Though not a cure-all for predator problems, guarding dogs are a good first line of defence in many types of farm operations, and as a supplement to other methods of non-lethal predator control (Linhart *et al*. 1979; Green & Woodruf 1980; Green *et al.* 1984; Marker *et al.* 2005). Guard dogs are effective against a wide range of predator species (Baker *et al*. 2008) even though they can be challenged by certain predator species such as wolves (*Canis lupus*) and grizzly bears (*Arsus arctos*) (Treves & Karanth 2003). Traditionally, livestock guarding dogs were selected from locally available breeds that portrayed proper guarding behaviour (Rigg 2001, Coppinger & Coppinger 2005). To date almost 40 breeds have been trained for the purpose of livestock protection worldwide (Green & Woodruff 1988; Gonzalez *et al*. 2012). Mixed breeds of dogs are also considered a good choice as not only are they efficient in reducing predator attacks, they are affordable, easy to obtain and are a low liability (Black 1981; Black & Green 1985; Gonzalez *et al*. 2012). Removing them due to lack of performance or other related reasons does not result in a significant loss of investment as they are generally less costly to acquire (Black & Green 1985). Over and above these characteristics, mixed breeds adapt easily to most environmental conditions and this makes them even more suitable for use in many parts of the world (Gonzalez *et al*. 2012).

Using guarding dogs requires patience on the part of the person/s responsible for training and looking after the dog which includes proper placement, feeding and timely veterinary care (Lorrenz & Coppinger 2002). The effectiveness of livestock guarding dogs varies between breeds (Green & Woodruff 1990) and these variations are attributed to factors such as the training of the dog, habitat and topography of the range land, availability and type of prey, the number of dogs used, livestock behaviour and other mitigation techniques that are used in combination with the guard dogs (Green *et al*. 1994). Moreover, the effectiveness of guard dogs can only be quantified when they are adults as younger dogs are often less effective owing to their age and physical maturity (Green *et al*. 1994).

In general, the livestock guarding dog method contributes greatly to reducing the risk of predator attacks (Ogada *et al*. 2003; Rust *et al.* 2011). Woodroffe *et al.* (2007) quantified that guard dogs reduce predation by 63%. The effectiveness of the livestock guarding dog is not necessarily related to either their breed or sex, but rather on the dogs' bond with the animals it needs to protect (Green & Woodruff 1980; Marker *et al*. 2005). This bonding, which is supplementary to a dog's natural aggression toward predators should be established in the early stages of puppy development to ensure that the dog becomes trustworthy, attentive and protective (Coppinger *et al*. 1988; Gonzalez *et al*. 2012). Another factor that increases the effectiveness of livestock guarding dogs is the presence of humans both at the homestead and in the veld (Musiani *et al.* 2003). While the method is generally cost effective, the cost implications are sometimes compromised by factors such as the annual rate of predation as well as the dog's longevity, purchase and upkeep costs (Green *et al*. 1984). In terms of predator conservation, the use of livestock guarding dogs reduces the incidents of lethal predator removals by farmers thereby not only increasing the survival of predators but also facilitating the movement of predators on farmlands thus increasing the available habitats to predators in these areas (Rust *et al.* 2011).

While the use of livestock guarding dogs has been found to work effectively against various predator species over a vast array of environments and landscapes (Marker *et al*. 2005), their effectiveness becomes compromised particularly in mountainous and densely vegetated landscapes as well as when the dogs guard a herd of sheep that disperses too much (Hansen & Smith 1999). Therefore, using guard dogs under such circumstances requires an increased number of dogs per livestock herd in order to improve their efficiency (Urbigkit & Urbigkit 2010). The efficiency of livestock guarding dogs is further reduced when the number of animals is too large, for example one dog will not be able to effectively guard a herd of 100 stock (van Bommel & Johnson 2012) and hence the need for a balanced guard dog/livestock ratio. Although there is limited information on the required guard dog/livestock ratio, increased number of dogs in one herd has been found to be more effective in safeguarding livestock against predation (Mertens & Promberger 2001). In addition, the livestock guarding dog technique works more effectively in fenced areas than in open range systems because fencing helps to keep the herd together within a limited space (Andelt 1992).

2.1.3.3 Use of predator-proof kraals

One conflict mitigation method used across the globe by livestock owners is physical deterrents or predator-proof barriers such as fences and bomas (referred to here as kraals) to confine livestock at night time (Ogada *et al*. 2003; Moruthi 2005; Woodroffe *et al.* 2007). Although construction of kraals can sometimes be costly especially where local building materials are not readily available, the benefits of using predator proof kraals prevail over the costs related to their construction when implemented as a long-term measure to control predation (Manoa 2016). The main advantage of these enclosures is that they are usually effective in keeping out predators.

Because they are mostly small in size (Distefano 2004) with circumferences normally ranging between 110m-400m (Manoa 2016), an additional advantage of kraals is that they do not occupy a lot of space within habitats thus reducing potential obstruction to wildlife and allowing species to move freely between different habitats (Distefano 2004). The effectiveness of these enclosures is however dependent on proper construction (Espuno *et al*. 2004) which is dependent on the design and cost (Baker *et al*. 2008, Weise *et al*. 2018). Commonly used materials include stone, mud, thorny tree branches, barbed wire or mesh wire fencing, the use of which is often determined by the cost and availability of the material at one particular location (Distefano 2004; Barker 2008).

Despite being labour intensive, densely constructed kraal walls using materials such as thorny branches provide effective livestock protection (Ogada *et al.* 2003; Woodroffe *et al*. 2007), the main limitation being that using high volumes of tree branches is sometimes detrimental to local plant species diversity (Okello *et al.* 2001). Although predator proof kraals require regular maintenance and enclosures do not guarantee 100% protection of the enclosed animals, previous studies (Lichtenfeld *et al*. 2015; Manoa & Mwaura 2016) have demonstrated more than a90% reduction in nocturnal livestock losses in African communal rangelands when livestock is enclosed at night. The effectiveness of predator proof enclosures is however sometimes compromised by the size, livestock number, number of entrances as well as the behaviour of the predator species targeted (Lichtenfeld *et al*. 2015; Manoa & Mwaura 2016). Therefore, the design of the enclosure and the material used should be guided primarily by the behaviour of targeted predator species (Hoare 1992; Mishra 1997; Sekahr 1998; Butler 2000; Distefano 2004).

For example, spotted hyena (*Crocuta crocuta*) accounted for 37% of livestock attacks inside kraals in Kenya, while lions accounted for 34% of the attacks (Manoa & Mwaura 2016).

Despite its limitations, the use of kraals is crucial and very effective especially when used in combination with other conflict mitigation methods (Treves & Karanth 2003). The importance of combining kraals with other conflict mitigation techniques is necessitated by the fact that the majority of livestock predation tends to happen outside kraals when the livestock is released to graze (Manoa & Mwaura 2016). In their study conducted in the Amboseli region of Kenya, Manoa & Mwaura (2016) found that 76.4% of predator attacks on livestock occurred during the day when livestock were grazing away from the kraals as compared to 23.6% that occurred at night when livestock was kraaled. In situations where livestock is left grazing outside the kraals at night (Loveridge *et al*. 2017) or when the structure of the kraal is too weak to prevent predator access (Broekhuis *et al*. 2017), predation increases significantly. These notions thus reaffirm the effectiveness of predator proof enclosures as a measure to protect livestock depredation particularly when the structure is well reinforced (Hazzah *et al*. 2014).

The practice of night kraaling can be of some detriment to the overall weight gain of livestock as kraaling reduces grazing time (Ayantunde *et al*. 2002). Livestock grazing at night supplements the grazing time lost by livestock during the heat of the day and helps the livestock to maximize its forage intake when heat stress is reduced due to cooler night temperatures (King 1983). In the Sahel region of West Africa, Ayantunde *et al*. (2002) found that excessive heat during the day caused the animals to graze for shorter periods before resting in the shade whilst waiting for temperatures to drop. The effects of kraaling livestock at night however also varies between the wet and dry seasons. Night kraaled livestock tend to lose weight more during the dry season when pasture is insufficient, and this often forces livestock owners to provide supplementary feeding in order to enhance livestock reproduction performance (Joblin 1960; Ayantunde *et al*. 2000).

2.1.4 Other conflict mitigation methods

2.1.4.1 Translocation

Translocation of predators in reaction to livestock predation has been in practice for many decades throughout North America and Southern Africa (Rogers 1988) as an alternative to lethal control (Linnel *et al*. 1997) especially when other preventative control measures were considered to be ineffective (Distefano 2004). The method entails live capture and relocation of the alleged problem causing animal from a problematic area to a completely new site (Linnel *et al*. 1997; Distefano 2004). Sometimes the damage causing animal is taken back to its original home range hoping that the negative experience of travelling will discourage it from going back to the conflict zone (Linnel *et al*. 1997). Although this method has gained popularity among many country states, translocation has proved to be much less successful than originally thought (Linnel *et al*. 1997; Distefano 2004; Athreya *et al*. 2011). Firstly, releasing predator species into an area that is already occupied by individuals of the same species can result in high levels of aggression and infanticide among the competing individuals (Treves and Karanth 2003). Furthermore, mortality of translocated animals can result from capture stress, injuries and long distances travelled (Linnel *et al*. 1997). Sometimes individuals are also able to travel back to their original translocation zones within a reasonable amount of time after translocation (Rogers 1988). In addition, translocation does not guarantee a solution to human-predator conflict as the relocated animal may still attack and kill livestock at its release site (Stander 1990). The success of translocation as a conflict mitigation method is therefore reliant on the availability of a release site that is free from any potential form of competition yet providing a suitable habitat for the survival of the translocated animal (Linnel *et al*. 1997). Moreover, the translocated animal should be released at a site that is far enough so that it cannot easily return to its original site (Treves & Karanth 2003). If the translocated animal dies shortly after translocation, the method should thus be viewed as indirect lethal removal of problem causing predators (Treves & Karanth 2003). Furthermore, translocation is extremely expensive as it requires specialized equipment and skilled personnel (Jackson *et al*. 1994). Due to the above factors which often result in high incidences of predator mortalities associated with translocation, the method is generally unsuitable for many situations (Treves & Karanth 2003).

2.1.4.2 Lethal predator removal

Lethal control technique has been practiced for many years as a tool that seeks to remove problem animal from human and livestock areas (Breitenmoser *et al*. 1998; Woodroffe *et al.* 2005; Daly *et al*. 2006). The method entails deliberate reduction or removal of damage causing animals in an area in order to protect humans and their property (Treves & Naughton-Treves 2005). In some instances, lethal predator control is perceived as effective and a comparatively cheaper method of dealing with livestock depredation (Mitchell *et al*. 2004). Most of the lethal methods used such as gin trapping, poisoning and snaring are indiscriminate and often eliminate even non-problem causing animals (Bamford *et al*. 2007). An additional disadvantage of lethal control is that livestock owners are exposed to the risk of being counter attacked by predators yet the method does not always bear the desired results of limiting livestock depredation incidences (Treves *et al*. 2016).

Although in principle, lethal removal of predators can have devastating effects on predator populations (Woodroffe *et al*. 2005), lethal removals which promote selective targeting of problem causing individuals in areas of high conflict as opposed to the overall reduction of a population (Stahl *et al*. 2001) has the potential to minimize the conflict between people and wildlife without posing any risk to the population of the species in question (McCullough 1996; Treves & Naughton-Treves. 2005; Woodroffe *et al*. 2005). The effectiveness of such control methods are based on the assumption that there are certain individuals within a population that are more problematic and hence subject to elimination (Stahl *et al*. 2001). In northern Kenya selective lethal removal of stock-killing lions resulted in a considerable reduction in the number of livestock attacks (Woodroffe *et al*. 2005). In addition, lethal control methods can increase tolerance of predator presence within communities especially where livestock attacks are minimal (Stahl *et al*. 2001). However, if not applied correctly, lethal control can lead to the extinction of predator species as was the case with the thylacin wolf (*Thylacinus cynosephalus*) in 1930 and the Falkland Island wolf (*Dusicyon australis*) in 1876 (Paddle 2000; Macdonald & Sillero-Zibiri 2004). Therefore, wherever lethal control method is considered, it should be carried out with extra caution to ensure that the intended results are gained without negatively impacting on the population viability of the species controlled (Treves & Naughton-Treves 2005).

CHAPTER 3

Study Area

The study was conducted in Jwana Game Park (JGP) and surrounding farmlands in Botswana (Figure 3.1). The JGP (24°33'09.3''S, 24°43'38.0''E) which is owned by Debswana Diamond Mining Company, is a 19, 085 hectare reserve located in the south-western district on the edge of the mining town called Jwaneng, about 180km west of Gaborone, Botswana's capital city. A few years after the establishment of Debswana Jwaneng Mine in 1980, management decided to raise a security fence to prevent illegal hunting of the few animal species that happened to occupy the area at the time of mine establishment. The species included red-hartebeest (*Alcelaphus caama*), blue wildebeest (*Connochaetes taurinus*), ostrich (*Struthio camelus*), springbok (*Antidorcas marsupialis*), steenbok (*Raphicerus campetris*), duiker (*Sylvicapra grimmia*) and black-backed jackal. During the late 1980's existing populations of various animal species were replenished with relocation of species from other reserves to increase genetic diversity. Species such as gemsbok (*Oryx gazelle*) and eland (*Taurotragus oryx*) thought to have previously occupied the area were introduced. This introduction prompted the construction of additional artificial water points to increase water supply to the park as there are no rivers in JGP.

Currently, the park is stocked with various game species including red-hartebeest, impala (*Aepyceros melampus*), springbok, steenbok, common duiker, blue wildebeest, gemsbok, kudu (*Tragelaphus strepsiceros*), eland, giraffe (*Giraffa camelopardalis*), zebra (*Equus burchellii*) white rhino (*Ceratotherium simum*) and warthog. Large predators include leopard, caracal, cheetah, jackal and brown hyena. Large birds such as ostrich (*Struthio camelus*), kori bustard (*Ardeotis kori*) and secretary bird (*Sagittarius serpentarius*) are also found in the park.

Results of aerial wildlife population census carried out between 2008 and 2018 are presented in Table 3.1 below.

Table 3.1: Results of JGP wildlife population census for the years 2009-2018

	Census Year									
Species	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Blue wildebeest	167	181	169	154	204	213	227	254	261	300
Cheetah	0	0	0	0	0	0	0	0	0	0
Grey duiker	5	15	20	25	21	21	32	58	25	26
Eland	434	606	787	755	482	491	599	483	583	606
Gemsbok	235	246	221	283	199	222	265	311	318	346
Giraffe	29	32	30	31	34	38	42	39	39	44
Brown hyena	0	0	1	0	0	0	1	0	0	1
Impala	95	93	120	104	17	183	256	309	342	413
Jackal	0	0	0	1	0	0	0	0	0	0
Kudu	26	39	38	35	15	10	19	11	11	21
Leopard	0	0	0	1	0	0	0	0	0	0
Ostrich	18	13	13	12	16	18	33	45	48	56
Red hartebeest	137	112	112	159	194	161	143	172	118	195
Rhino	4	6	6	7	6	8	10	10	11	12
Steenbok	11	23	23	16	14	14	32	64	74	58
Springbok	111	118	118	103	106	133	192	168	241	348
Warthog	86	145	145	177	162	227	275	195	136	161
Zebra	166	200	186	177	165	206	267	349	392	479

At the time of my study, JGP had nine artificial water points that were evenly distributed across the park. The boundary was fenced with a 2.4m high game-proof welded wire mesh fence which is maintained by Debswana Mining Company. The road network comprises of mainly dirt roads and a few graveled roads (Figure 3.1).

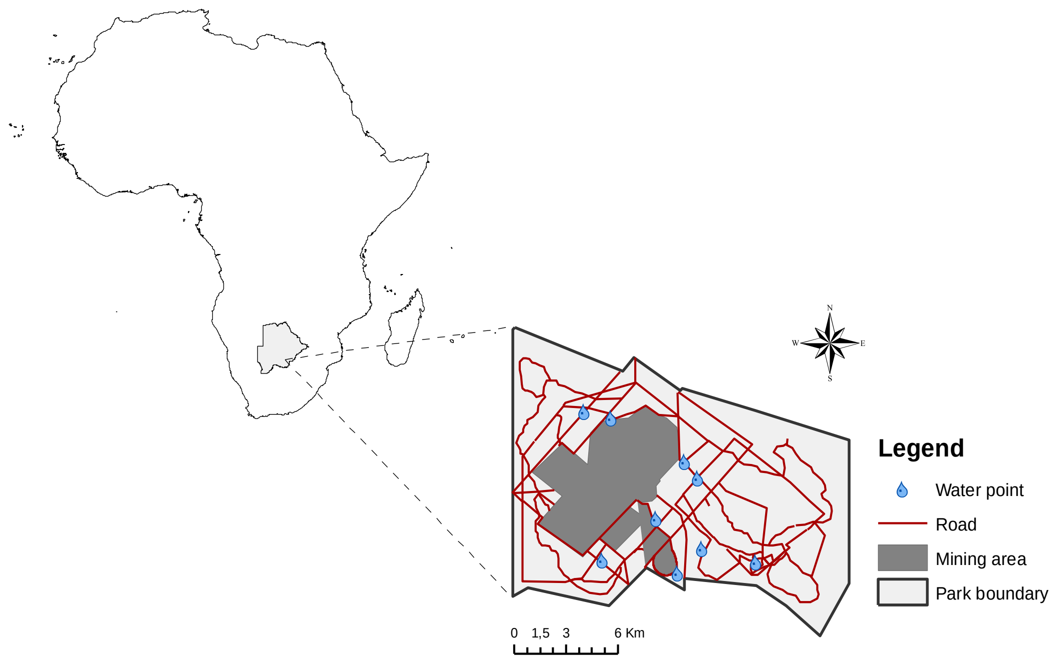

Figure 3.1 Location Map of Jwana Game Park showing the relative position of all water points, the mining area (dark shade), park roads and boundary (dark outer polygon)

Although the park is mainly open for use by mine employees, the general public is also allowed to visit but only in the company of Debswana mine permit holders. Activities carried out in JGP include game drives, picnics and environmental education activities for school children. Debswana Jwaneng mine which is surrounded by JGP was still fully operational during my study. The JGP falls within the IUCN's category "1a" of protected area categories which are referred to as Strict Nature Reserves. Protected areas in this category are set aside to conserve biodiversity with controlled and limited human visitation, use and impacts to ensure protection of conservation values (Dudley 2008). With the exception of the people who live in Jwaneng, a town that is situated about 2km from the southern part of the park, communities who occupy the land surrounding JGP practice crop and livestock farming at both subsistence and commercial levels.

3.1 Geology and Topography

The JGP is located on the western edge of the hard-veld with Kalahari sands top soil deposits (Smith *et al*. 2007). The ground slopes gently towards the Naledi valley, which descends from the southeast to northwest (Smith *et al*. 2007). The substratum is made up of argillaceous sediments of the Transvaal super group with deposits of diamondiferous kimberlites which are covered by up to 60m of Kalahari formation sediment (Smith *et al*. 2007). The soils are dark reddish-brown and medium textured with varying depths and are associated with dark coloured clay soils and medium-fine textured brown-grey mottled soils in depressions (Smith *et al*. 2007). The topography of JGP is predominantly flat with an average altitude of 1182 meters above sea level.

3.2 Climate

The JGP occurs within a summer rainfall area, with the average annual rainfall of about 449mm occurring mainly between October and April each year (Department of Meteorological services 2018). Average minimum and maximum temperatures range from 3.5°C in winter (May to August) to 35°C in summer (September to April). The highest temperature recorded was 39.6°C, recorded in December 2018 whilst the lowest temperature recorded was -4°C in winter recorded during July 2018 (Department of Meteorological services 2018).

3.3 Vegetation

The study area is located on the Zambezian Kalahari-high veld regional transition zone (White 1983) and vegetation is classified as Kalahari-*Vachellia* wooded grassland and deciduous bush-land which sits on the boundary between *Terminalia sericea*-*Vachellia erioloba* sand veld and

*Vachellia mellifera-Vachellia leuderitzii-Boscia albitrunca*s and veld (Bekker & De Wit 1991). The vegetation is predominantly open semi-wooded savanna mixed with moderately thick bush (Smith *et al*. 2007; Houser 2008). Dominant tree species include *Vachellia mellifera, Vachellia leuderitzii* and *Terminalia sericea* (Houser *et al.* 2009). Smith *et al*. (2007) identified four habitat types in JGP: the *Stipagrostis-Eragrostis Schmidtia* grassland (hereafter called grassland) which constitutes 37% of the reserve and *Terminalia sericea-Vachellia-Bauhinia* bush-land (hereafter called bush-land) which contributes to 52% of the park's habitat types (Smith *et al*. 2007). *Peltophorum africanum* bush-land makes up 0.23% of the identified habitats, and the fourth habitat referred to as the 'bare ground' habitat contributes to 10.77%. The 'bare ground' habitat is a result of the mining activities that took place in the area before the park was demarcated a protected area and is separated from the rest of the park area by a game proof fence and no mammalian species have been introduced into this area.

3.4 Land use

The land adjacent to JGP is mainly used for pastoral farming where pastoralists practice both livestock and crop farming. Farming is at both subsistence (in the communal areas) and commercial levels (in the fenced cattle ranches) (Houser 2008; Boast *et al*. 2011). Livestock kept include goats, sheep, donkeys, horses, cattle and other domestic animals such as dogs and cats. Livestock population numbers obtained from Botswana Department of Animal Production census (2015) are shown in Figures 3.2 & 3.3 below.

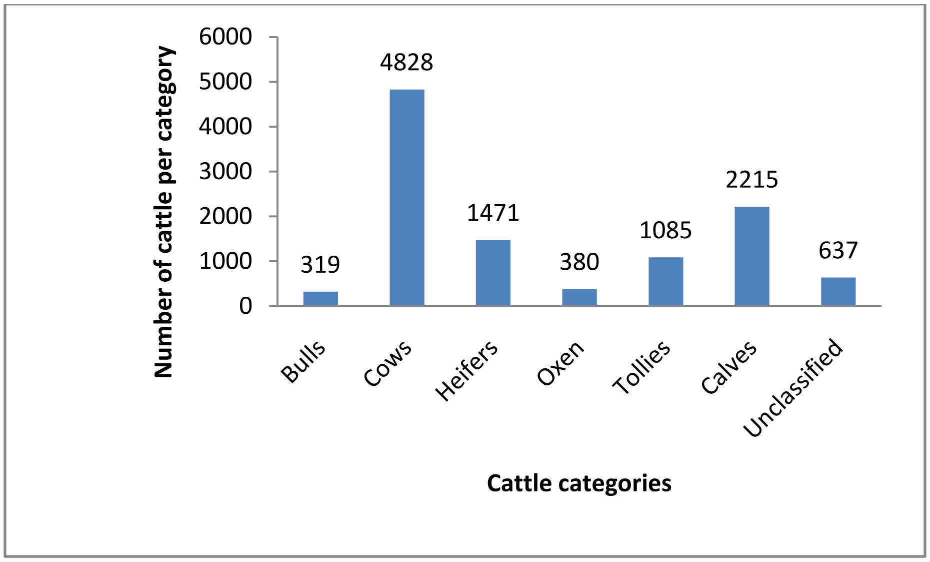

Figure: 3.3 Jwaneng 2015censuses for livestock other than cattle

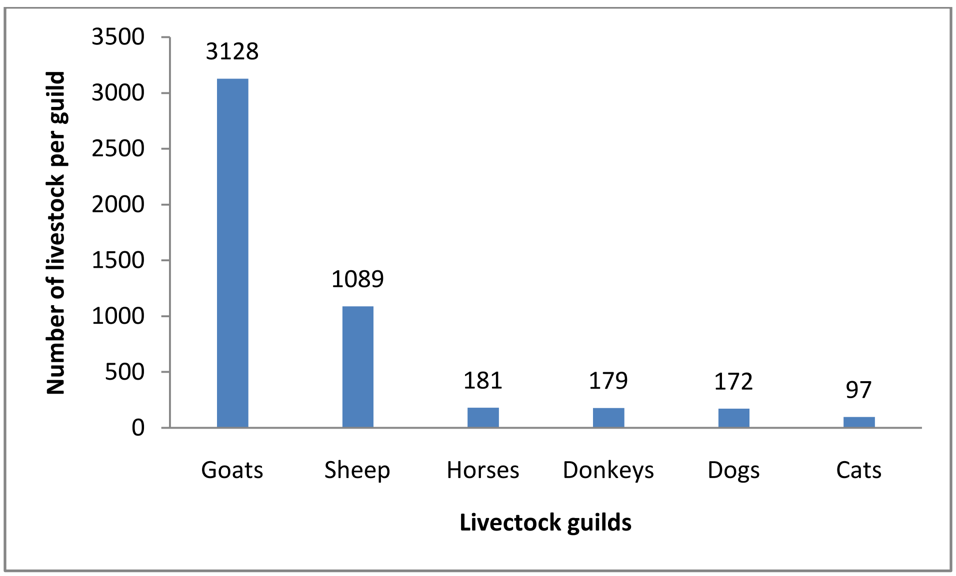

Figure 3.2 Jwaneng 2015 census for cattle presented in various groups, n=10935

Although there is limited documented information on the main source of income for people living in this adjacent land, arable farming remains the single most important economic activity in the area, with some community members being employed by the mining company.

CHAPTER4

Occupancy of large predators in Jwana Game Park and the potential for Human-Wildlife-Conflict on the adjacent livestock farming areas

4.1 Introduction

Conservation of biodiversity in Africa could not have been successful without the historical demarcation of protected areas (Kiringe & Okelo 2007; Muhumuza & Balkwill 2013). Many of these historical demarcations were set by traditional human societies in the form of hunting reserves, religious forests and common grounds (Chandrashekara & Sankar 1998), which were areas of land that were managed for the protection of biodiversity and other natural processes through the restriction of incompatible land uses (Possingham *et al*. 2006). The segregation of protected areas adds to existing important tools that are used to maintain habitat integrity and species diversity (Bruner *et al*. 2001; Hansen & Defries 2007; Adam *et al*. 2008). Over and above the protection of biodiversity and habitats, protected areas have also been found to play a key role in the conservation and/or sustainability of ecosystem services such as carbon storage, pollination and soil stabilisation (Armsworth *et al*. 2007; Darimont *et al*. 2010).

Globally about 15.5% (19.9 million km^2) of available terrestrial land has been demarcated for biodiversity conservation (Soutullo 2010; Juffe-Bignoli *et al*. 2014) while in Africa14.7% (approximately 3.6 million km^2) of land has been set aside for the same purpose (Juffe-Bignoli *et al*. 2014). Whether fenced or unfenced, many protected areas are still able to attain their set objectives of maintaining ecological processes and native species preservation because of minimized and/or constrained anthropogenic human activities (Possingham *et al*. 2006). Despite this, understanding the efficacy of protected areas is still a challenge (Sutherland *et al*. 2011) mainly due to inadequate substantiation on the extent to which species populations are conserved (Geldmann *et al*. 2013).

Although protected areas are generally established to achieve a primary goal of biodiversity conservation, the management of protected areas varies from one protected area to another (Dudley 2008). For example, some protected areas are fenced while others such as the Khutse Game Reserve (Weilenmenn *et al*. 2010), Northern Tuli Game Reserve in Botswana (Jackson *et al*. 2012) and Gonarezhou National Park in Zimbabwe (De Garine-Wichatitsky *et al*. 2010; Gandigwa *et al*. 2013) are unfenced to allow for natural dispersal and other ecological processes to take place (Newmark 2008). Such management differences have implications for the ecological impacts on biodiversity conservation as well as on the communities that live in the proximity of these protected areas (Newmark 2008).

Fenced protected areas may assist in reducing human-wildlife interactions with communities that live adjacent or close to protected areas as these fences can to a certain degree restrict the animals within the boundaries of protected areas (Newmark 2008; Ferguson & Hanks 2010). These physical barriers also reduce the risks of disease transmission between wildlife and domestic animals while also increasing the security of protected areas as well as endangered and indigenous species that occur within the boundaries of these protected areas (Hayward *et al*. 2009; Ferguson & Hanks 2012).

While protected areas provide refuge for indigenous and endangered species, they have not been entirely successful in curbing the conflict between man and wildlife especially on agricultural land that is situated close to protected area boundaries. Naturally, protected areas are only segments of the entire ecosystem and as such, species tend to leave protected areas and cross into surrounding farmlands to access resources that they require (Hansen & DeFries 2007; Newmark 2008). In addition, some protected areas are situated in harsh and low quality habitats which consequently force individuals and/or species to search for required resources in the surrounding landscape particularly during droughts (Scott *et al*. 2002).

Large mammalian predators that disperse from or move between protected areas continue to have impacts of some sort on the livestock that graze on the adjacent rangelands (Ferguson & Hanks 2012). For example, a lioness from Kruger National Park, South Africa was recorded on a camera trap escaping through the western boundary fence to predate on livestock belonging to communities who reside on the neighbouring unprotected land (Ferguson & Hanks 2012). A similar occurrence was observed around the Waza National Park in northern Cameroon where GPS collared lions were found to be killing livestock on adjacent farmlands and it was further determined that livestock made up to 21.6% of these lions' diet (Tumenta *et al*. 2013). Similar observations have been made in Namibia's Etosha National Park (Stander 1990).

Due to perceived or actual threats of predators on livestock, negative perceptions of local communities towards protected areas are of global concern. Such perceptions are a result of the ongoing movement of wild animals between protected areas into neighbouring farmlands (Moruthi 2005). In some areas this situation is exacerbated by the unrestricted movement of large animals which allows them to move through both a designated protected area and surrounding unprotected pastoral lands (Moruthi 2005). The conflict tends to affect communities that are located closer to protected areas more than those further away (Botswana: Gusset *et al*. 2009; Tsavo Conservation Area, Kenya: Makindi *et al*. 2014).

Understanding this conflict can only be achieved through the monitoring of predator populations within protected areas and surrounding landscapes. However, investigating the ecology of large predators is challenging as most large predator species tend to be solitary, elusive and predominately nocturnal (Balme *et al*. 2007; Bowkett *et al*. 2006; Wolfe *et al*. 2015). In addition to their cryptic behaviours, predator species generally occur at low densities (Ray *et al*. 2005). The challenge can be even greater in areas that are less accessible such as densely vegetated plant communities (Mohd-Azlan 2009).

As a general concern, predator populations continue to be threatened by multiple factors such as habitat destruction and fragmentation (Kummer & Turner 1994; Curran *et al*. 2004) and persecution through indiscriminate hunting, trapping or poisoning (Mateo-Tomas *et al.* 2012). For this reason, predator population monitoring remains a critical tool in wildlife management as it helps managers to acquire important information on the conservation status of a targeted species (Driessen & Hocking 2008). This information further assists management to evaluate the efficiency of their management actions in relation to the set objectives by providing some feedback on management strategies required to improve the conservation approach in place (Yoccoz *et al*. 2001; Martin *et al.* 2007).

The main impediment in the selection and implementation of a population monitoring technique is finding an appropriate method that meets the objectives of the project and/or the species under study using resources that are available (Zuhdi 2017). Bisbal (2001) identified three types of monitoring protocols: baseline monitoring, trend monitoring and effectiveness monitoring. Baseline monitoring is an assessment of a condition and/or situation of a site before and after an intervention. Effectiveness monitoring evaluates the effectiveness of management strategies in relation to the achievement of set objectives, whereas trend monitoring is used to examine changes in predator populations over a prolonged period of time.

Generally, there are different population monitoring techniques used by conservationists across the globe and they either fall under direct methods (Thompson *et al.* 1998) or indirect methods (Thompson & Fleming 1994). Monitoring techniques also vary in implementation feasibility and cost (Kus & Beck 2001). Commonly used predator population monitoring methods include: Capture-Recapture or Mark-Recapture (Ovaskainen 2004; Miller *et al*. 2005; Manning & Goldberg 2010), faecal DNA analysis (Thomsen *et al*. 2012; Dana *et al*. 2016; Lopez-Bao *et al*. 2018), transect counts (Burnham *et al*. 1980; Stander 1998; Funston *et al*. 2001; Houser *et al*. 2009; Keeping 2014; Keeping & Pelletia 2014) and camera trap imagery (Rowcliffe & Carbone 2008; Rowcliffe *et al*. 2008; Marnewick *et al*. 2008; Rovero & Marshal 2009; Brassine & Parker 2015).

Since the inception of using camera traps during the early 1980s, camera trapping has received persistent advancement resulting from continuous improvements in photographic and digital technologies (Carbone *et al.* 2001). Camera traps have been widely used to examine species conservation status, population densities, territorial behaviours, habitat selection and estimates of species (for example: Seydack 1984; Griffiths & van Schaick 1993; Mace *et al*. 1994; Marnewick *et al*. 2006; Kelly & Holub 2008; Rowcliffe & Carbone 2008). Camera trapping has become a common method used to investigate elusive predators due to the relative cost effectiveness and minimal obtrusiveness of the cameras to wildlife and the environment (Henschel & Ray 2003; Marnewick *et al*. 2008). The method provides objective records of present terrestrial animals and also allows for identification of individuals within a species that has unique pelage patterns such as cheetah (Marker *et al.* 2008; Marnewick *et al*. 2008), leopard (Henschel & Ray 2003), bobcat (*Lynx rufus*) (Heilbrun *et al*. 2003), puma (*Puma concolor*) (Kelly *et al*. 2008); brown hyena (Kent & Hill 2013) and jaguar (*Panthera onca*) (Karanth 1995). Detectability for such species can then be integrated into a capture-recapture model to examine their abundance in an area (Nichols 1992).

Camera traps record images of any organism that passes in front of the camera and triggers the infra-red sensors that are fixed within the camera trap unit (Marnewick *et al*. 2008; Rowcliffe *et al*. 2008). These cameras provide spatial and temporal individual records with minimized interruptions on the animal photographed (Reeves 2010). Camera traps are operational in a vast array of climatic conditions (Marnewick *et al*. 2008) as well as in vegetation or sites with poor accessibility to researchers (Karanth & Nichols 1998). In addition, cameras are very effective in capturing images of cryptic and nocturnal species (Karanth & Nichols 1998). Camera trapping has been very successful in the identification of rare and elusive species that could not be detected through other monitoring techniques such as sign and distance sampling (Silviers *et al*. 2003; Sanderson & Trolle 2005; Tobler *et al*. 2008; Rovero & Marshal 2009). Over and above their ability to capture images at any time over a 24-hour period, camera traps are also efficient in providing information on species presence-absence (Linnel *et al*. 1998), habitat use and distribution (Henschel & Ray 2003), as well as population structure (Silveira *et al*. 2003).

When placing camera traps, it is critical to have an understanding of the biology of the species being investigated (Marnewick *et al*. 2008) as this will enhance a systematic set up of cameras and increase capture probability for animals that occupy the study area (Silver *et al*. 2004). However, like many other population monitoring techniques, using camera traps requires careful assessment of the area to ensure their efficiency and reliability (Kays & Slauson 2008). While the technique has proven to be successful in collecting valuable conservation information (Karanth 1995, Silver *et al*. 2004), its applicability remains limited by the fact that most mammal species do not have individually recognizable pelagic patterns thus making it difficult to identify individuals from images recorded. However, when abundance cannot be estimated owing to the difficulty of identifying individuals within a species, occurrence or occupancy (Ψ) modeling remains an option for estimating the percentage of an area occupied by the species being studied (MacKenzie *et al.* 2002).

Camera trapping data can also be used to develop detection histories of species within a sample site by recording detection and non-detection information based on the capture events of a particular site (MacKenzie *et al*. 2002; MacKenzie *et al.* 2006). Detection histories can then be used to predict estimates of site occupancy which is still applicable even when a detection history at a site is less than one (MacKenzie *et al*. 2002). In general, occupancy models determine the probability with which a site is occupied by the species being investigated.

However, because the model was adapted from the original mark-recapture model, it also allows for possible detection of the species that may have happened to escape detection during sampling (MacKenzie *et al*. 2002; MacKenzie *et al*. 2006). Non-detection may result in cases where the species being investigated does not occupy the sample site or when the species occupies the site but is not detected by the sampling technique used (Bailey *et al*. 2007).

Occupancy models have been used by researchers to examine species-habitat association (Scott *et al*. 2002), species distribution (Fisher & Shaffer 1996), and meta-population dynamics (Hames *et al*. 2001). In some instances, occupancy models have also been used to evaluate the effectiveness of management actions with regards to applied conservation programs (Manley *et al*. 2004; Mazerolle *et al*. 2005). In addition, occupancy models afford researchers an opportunity to evaluate the potential factors that influence detection and occurrence of a given species at a site (MacKenzie *et al*. 2002). Occupancy modelling has also been found to be comparatively cost effective particularly because they are practically applicable and effective even on small sample sites (MacKenzie *et al*. 2006).

Where occupancy is investigated using camera traps, multiple camera traps are required to generate reliable data (Rovero *et al.* 2010). Furthermore, simulations have suggested that optimum species detection can be obtained by increasing the number of camera sites rather than increasing the number of survey days (Moruzzi *et al*. 2002; Rovero *et al*. 2010). However, to maximize capture probability, prolonged survey days are also necessary in areas where detection probabilities for species are unknown especially for less abundant species (MacKenzie & Royle 2005). In practice, species with a high detection probability would require less survey days to collect reliable data than those with low detection probability which require more survey days (Rovero *et al*. 2010). Species detection varies from one species to another due to various ecological factors that influence their detectability such as sex, age, social status, territoriality (Larrucea *et al*. 2007), distribution of reproductive females, occupation of the physical environment (Guil *et al*. 2010) as well as inter-specific and intra-specific competition (Harmsen *et al*. 2010). Where preliminary data is available, simulations can be performed to estimate the required number of survey days (Bailey *et al.* 2007) using programs such as GENPRES (Hines 2007) or MARK (White 2009). Although occupancy analysis should ideally meet certain key assumptions such as there is no change in species occupancy at the site throughout the survey period (MacKenzie *et al*. 2002), there is likelihood for violation of this assumption if the area sampled is smaller than the mean home range of the investigated species (Gray 2012).

Spoor counts have also been used by researchers to estimate population density and relative abundance for various wildlife species such as leopard, lion, brown hyena (Stander 1998; Funston *et al*. 2010; Kent & Hill 2013), caracal (Melville & Bothma 2006) and cheetah (Houser *et al*. 2009). The technique is comparatively cost effective, repeatable and less invasive than other direct count methods (Stander 1998; Jewell *et al*. 2001; Funston *et al*. 2010). Counting spoor can also be reliable and useful in estimating the relative abundance of a population (Panwar 1979). The spoor count technique has further been used to identify individual animals and differentiate between sex and age based on the shape and size of the spoor (Linnel *et al*. 1998). The technique can however be limited by factors such as climate and ground conditions which can make it difficult for researchers to detect spoor on the ground surface (Silveira *et al*. 2003). The efficiency of the spoor count method is generally maximised on sandy and muddy soils (Linnel *et al*. 1998; Funston *et al*. 2010; Bauer *et al*. 2014). Over estimation of population density using spoor counts is however possible if double counting is not avoided especially when projected estimates are not calibrated against other survey methods (Kent & Hill 2013). In this study spoor densities were used to determine predator species habitat preference relative to the park's available habitats.

The objective of this chapter was to investigate occupancy of medium-large predators, determine habitat utilization and establish if predators moved between the park and adjacent farmlands. From this objective the following research questions were addressed.

1. Which species of medium-large predators are present in JGP?
2. What is the occupancy estimate for medium-large predators in JGP?
3. Do medium-large predators use holes in the park's boundary fence to move between the park and the surrounding agricultural lands?
4. Is there an association between predator species occupancy and the distribution of holes under the perimeter fence of the park?
5. Does habitat preference influence occurrence of medium-large predator species in the park?

From the above research questions I predicted that:

1. Predator species' occupancy estimates were influenced by the presence of other predator species in the different cells.
2. Occupancy estimates were influenced by the number and distribution of intensively used fence holes in different sections of the park.

3. The number of intensively used holes was high in the sections of the park that are closer to the farmlands compared to those that are closer to Jwaneng town
4. The park's main habitats were used by various predator species in accordance to the habitats availability.

4.2. Methods

For the purpose of data collection, JGP was divided into four cells or sections (Figure 4.1), and spoor counts and camera traps were used to determine predator presence in JGP. The north-western section (64.7 km^2) of JGP was designated as 'cell one (C1)', the north-eastern section (49 km^2) as 'cell two (C2)', the south-eastern section (41.2 $km^{2)}$ as 'cell three' (C3) and the south-western section (52 km^2) as 'cell four (C4)'. Each of these cells was then further divided into four more/or less equal sub-sections, which were used to facilitate the placement of camera traps. For the purpose of this study, spoor referred to foot prints left on the ground surface by passing individual predators (Stander 1998). For the purpose of this study, medium-large predators refer to predator species of body weight exceeding 5kg (Stuart & Stuart 2006).

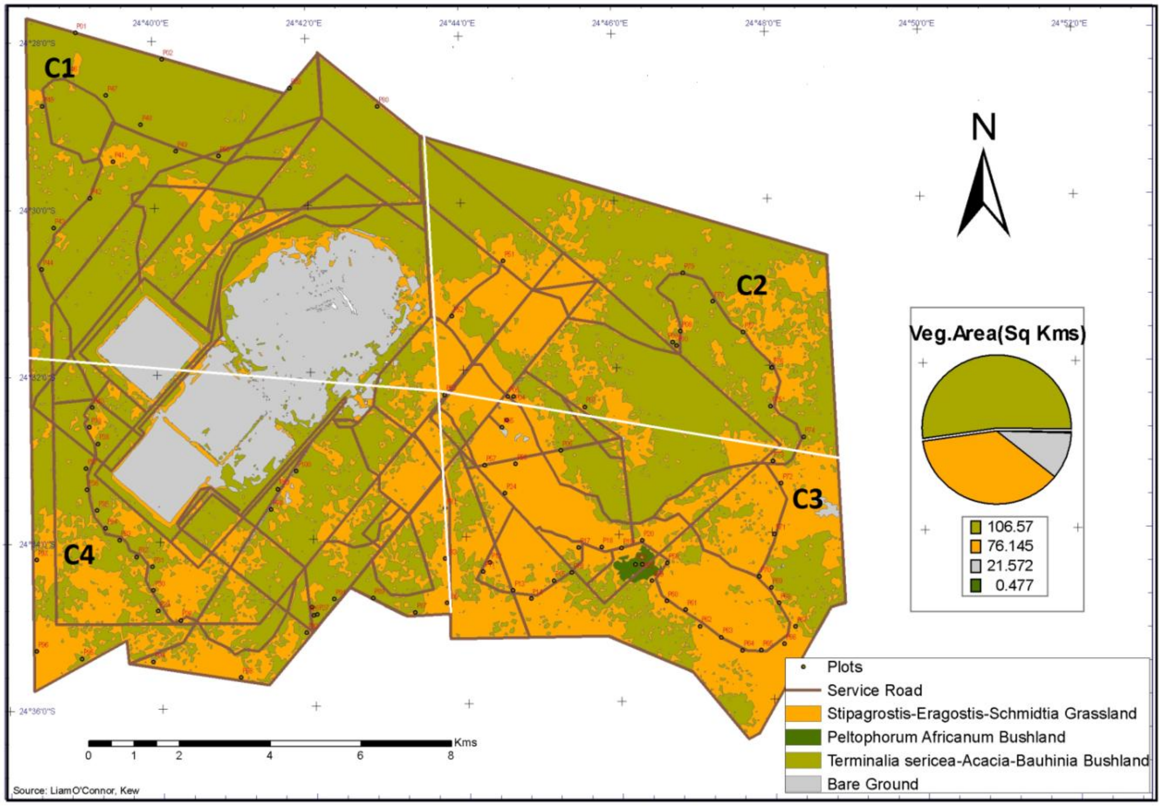

Figure: 4.1 Jwana Game Park showing divisional cells (C1-C4), primary vegetation classifications, park roads and mining area (Smith *et al.* 2007).

4.2.1 Potential utilization of holes by predators along JGP's boundary fence

As is common in fenced areas, holes dug by various animals occur underneath JGP's boundary fence. By virtue of their number, size and physical appearance, these holes can potentially be used by various animals including predators to move between JGP and adjacent unprotected areas, as well as for people to trespass and poach inside the park. To investigate the significance of these holes in terms of predator movement in and out of the park, JGPs boundary fence was surveyed once in order to map the locations and spatial distribution of these holes.

Each hole found was given a unique number for identification and the GPS coordinates were recorded. Each hole was allocated a utilization score which was derived based on the signs of repeated animal movement through each hole. Each hole was classified as intensively used (category 1), moderately used (category 2) or less-intensively used (category 3) (Figure 4.2).

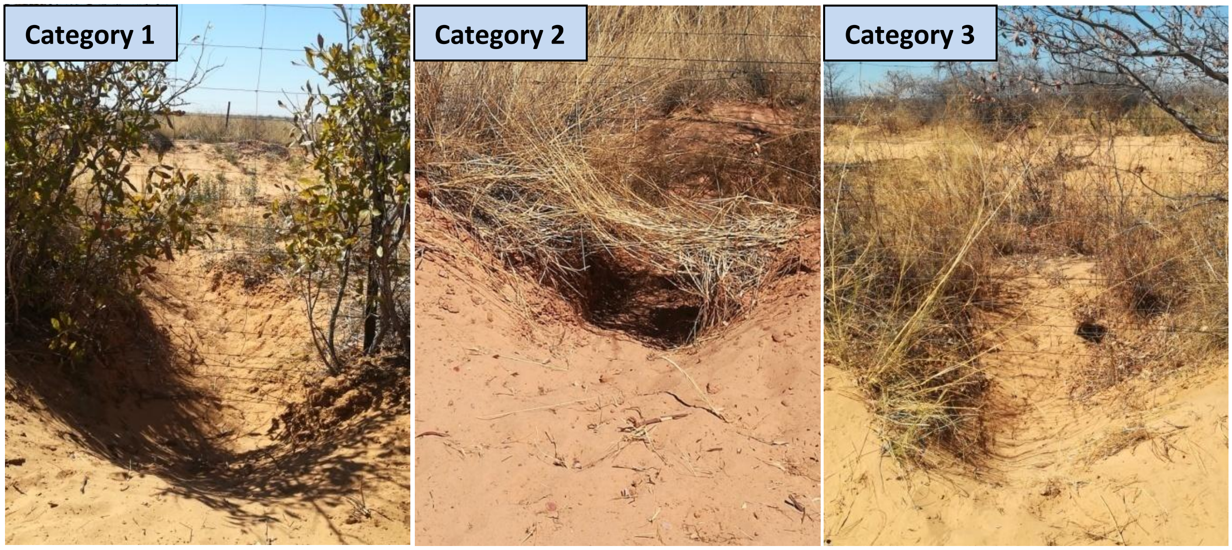

Figure 4.2 Classification of holes based on their utilization frequency. Category 1: intensively used, category 2: moderately used, category 3: less-intensively used.

Intensively used holes (category 1) were holes that had clear signs of repeated animal movements: mostly large in size and the paths that were used by animals to access these holes were also distinct. Moderately used holes (category 2) showed clear signs of animal movements but not as distinctive as the category 1 holes. The less-intensively used holes (category 3) were typically smaller in size than the other two categories and had either very little or no evidence of recent animal use. Scores were allocated to each of the three utilization categories to distinguish between the frequencies of animal movements through each hole in comparison to others. Scores were allocated as follows: intensively used (category 1) was allocated a score of 1, moderately used (category 2) a score of 2 and less-intensively used holes (category 3) a score of 3.

4.2.2 Occupancy of medium-large predators using camera trap survey

Fourteen Camera traps (11x Bushnell Trophy Camera Brown Model 119537 and 3x Cuddeback Capture 1125) were set up to collect data for the estimation of predator occupancy in JGP. Two camera traps were placed at one location (referred to as a camera station) facing each other (Karanth & Nichols 2010; O'Brien *et al*. 2003) within a subsection of each cell (Figure 4.3).

Figure 4.3 Spacing of camera traps set to monitor animal movement at the fence holes

Each cell had four more or less equal sub-sections determined by dividing each cell into four parts. The sub-sections were used to guide periodic rotation of camera traps within each cell (Rich *et al.* 2016). Each subsection of a cell (except in cell '4') had two camera stations at a time for 12 weeks before they were moved to the next sub-section within the same cell. Due to its comparatively small size as a result of the mining area overlapping into most part of it, cell '4' had only one camera station within a sub-section at a time. The rotation of the camera stations took place over eleven months from February to December 2015 to maximise capture probabilities especially for species that occurred in less abundance.

Camera stations were located approximately 2km apart and were mounted on poles and/or trees at about 40cm above the ground. Spacing between cameras varied from one camera station to the other, for example, cameras used to monitor holes were spaced based on the size of the hole to allow for better captures, cameras placed at the roads were mounted on either side of the road while those at the water holes were mounted on the trees standing on either sides of the water hole. No baits or lures were used to attract animals to the cameras. Eight of the 28 camera stations were positioned at intensively used holes (category 1) along the park's boundary fence to determine if predators moved in and out of JGP through these holes (Figure 4.4). These eight camera station locations were selected based on the score and position (see section 4.2.1 for details) of the holes in relation to the different divisional cells to ensure that they formed part of the standard camera placements within the respective cells. Although there are possibilities for predators to use category 2 and 3 holes, only intensively used holes (category1) were selected for location of camera sites in order to maximize the capture events.

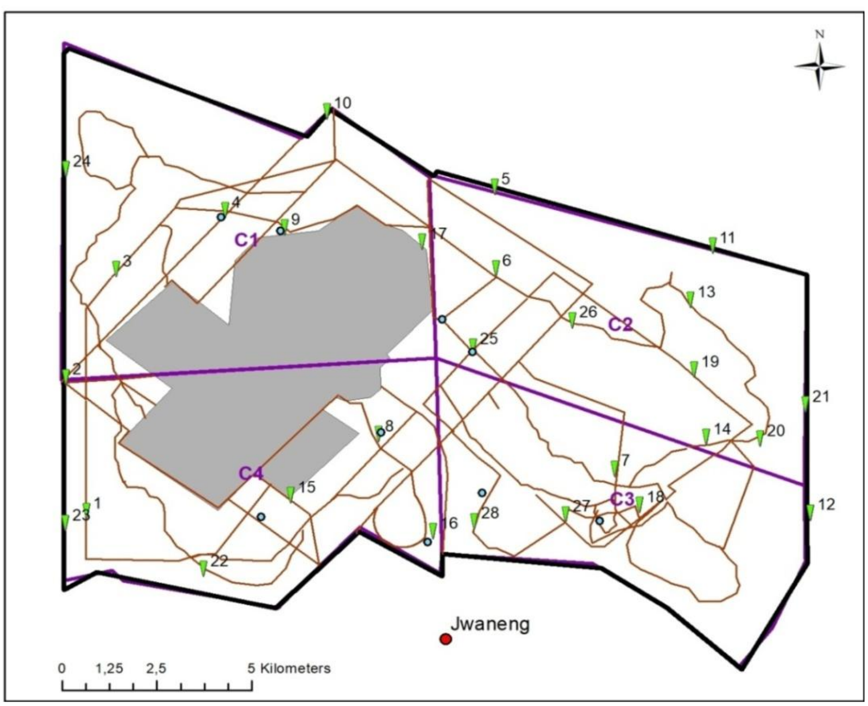

Figure 4.4 Locations and spatial distribution of camera traps (green triangles) within different cell divisions, (C1-C4) Water points (blue circles) and park roads are also illustrated.

Due to the temporal variation of predator activity, camera traps were set to operate continuously 24 hours a day. Cameras were checked every ten to fourteen days to change batteries and download images from the camera's SD card. The route used to access camera traps was standardized, so at the time of placement, cameras on the left-hand side of the road were labelled ‘‘A’’ while those on the right-hand side were labelled ‘‘B’’. Cameras were set to take only one image per capture and the activation time delay between images was set at 30 seconds (Boast *et al*. 2011). Both date and time was recorded on the images. Vegetation that may have triggered the infra-red sensor of the camera traps was cleared during each check of the camera traps.

4.2.3 Spoor density as a measure of predator species' habitat preference

A spoor survey was used to investigate the spatio-temporal distribution and abundance of predator species in JGP. Spoor counts were conducted along transects which were selected based on knowledge of the study area in terms of the substrate suitability for the detection of spoor during the surveys. The initial layout of transects was conducted by driving through the study area logging routes using a handheld GPS device. Transects were mainly along the park's management roads, which were characterized by sandy top-soil as these were suitable for rapid detection of spoor (Stander 1998; Funston *et al*. 2001). Transects were laid out to facilitate adequate coverage of the park's surface area (Figure 4.5) and minimize chances of double sampling (Burgener & Gusset 2003; Houser *et al*. 2009).

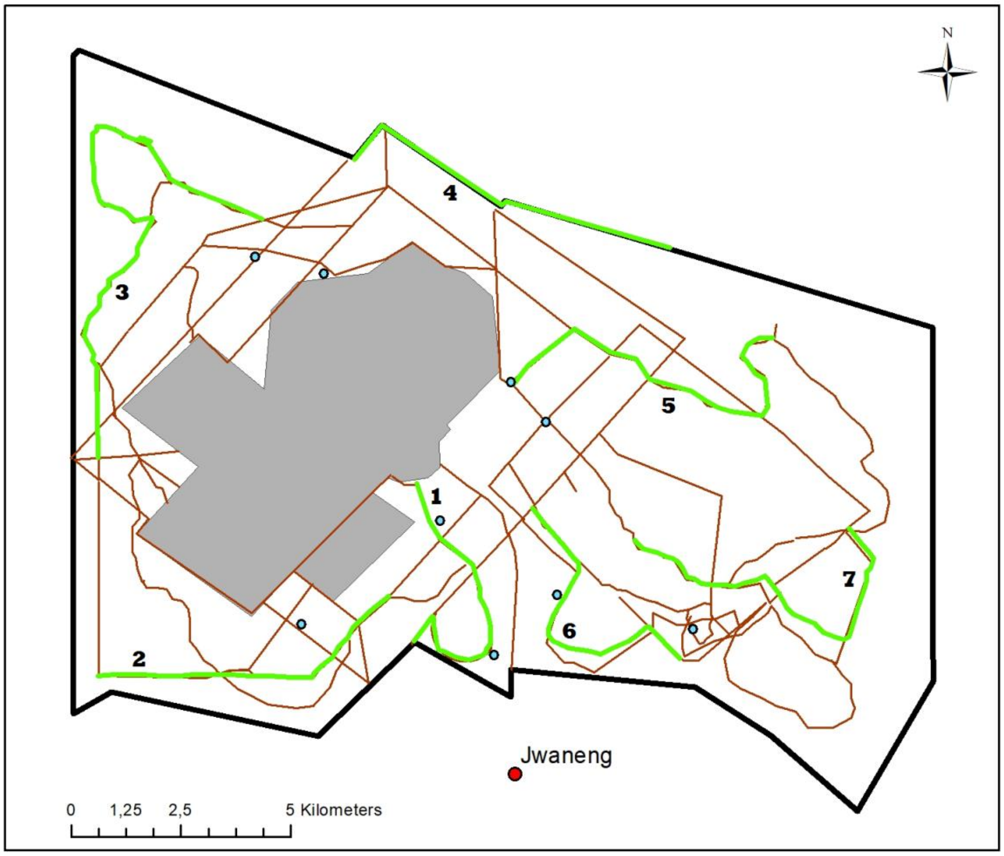

Figure 4.5 Spoor counts transect layout inside Jwana Game Park (green lines), n=7, distribution of waterholes (blue circles) and park roads (brown lines).

Spoor surveys were conducted by driving a vehicle along marked transects (Figure 4.5) for four consecutive days during the first week of each month from February to December 2015.Each transect was surveyed twice during each month's survey. Transects 1-4 were surveyed on day one of each survey week, transects 5-7 on the second day of each survey week and then this survey process was repeated on day three and four of each survey week. Transects were driven and sampled at about the same time each sampling day: (06h00 hours in summer and 07h00 hours in winter) for consistency and prior to the destruction of spoors by vehicles during the day. The distances of transects are presented in Table 4.1 below.

Table 4.1 Spoor survey transects and their respective distances

Transect	1	2	3	4	5	6	7
Distance (km)	7.32	7.48	13.82	8.52	9.57	9.62	7.48

To maximize the probability of finding spoor and to maintain consistency, the vehicle was driven at a constant speed of 12km/hr with two people (myself and field assistant) in a vehicle at a time (Figure 4.6). My field assistant was of the San origin and often they are used by researchers because of their expert knowledge and skills in spoor identification and interpretation (Stander 1998).

Figure 4.6 San tracker during spoor surveys (Picture by: M. Kokole)

When predator spoors were found, the vehicle was stopped, and the tracker identified the species to which the spoor belonged. The time, date, and GPS location of the identified spoor were also recorded. If similar spoor were encountered within 0.5 km from a recorded spoor and the tracker could not positively identify that the spoor was from a different individual than the one previously identified, the spoor was regarded as belonging to the same individual and therefore not re-recorded (Funston *et al*. 2010). Any spoor that could not be reliably identified was also not included. To prevent recording the same spoor twice within a survey week, only spoor that were less than 24 hours old were recorded. Each spoor identified and recorded was regarded as an individual and not as a family group (Stander 1998). Herbivore species that were found within 100m from transects were also recorded by counting their total number in a group during sampling.

Data from the predator spoor survey were also used to investigate habitat utilization in terms of habitat availability of medium-large predators on JGP as per Neu *et al.* (1974). Three of the four habitats that occur within JGP were included in the analysis: Grassland (7 614.5ha), bush-land (10 657ha) and *Peltophorum africanum* bush-land (47.7ha) (Smith *et al*. 2007). The *Peltophorum africanum* bush-land and the *Terminalia sericea-Varchellia-Bauhinia* bush-land habitat were combined for the purpose of this analysis (and referred to as bush-land) due to the former habitat's small size (47.7ha) as well as its similarity to the latter. As mentioned in chapter three, the bare ground habitat is the mining area inside the reserve and excludes any large animals by a game proof fence and was therefore excluded from the analysis.

4.3 Data analysis

4.3.1 Potential utilization of holes by predators along JGP's boundary fence

Data collected on the location of holes found under the park boundary fence were plotted on Quantum GIS software version 2.14.2 with GRASS 7.0.3 to visualize their spatial distribution. The total number of holes was used in relation to the total distance of the perimeter fence (82km) to determine hole density (number of holes/km). One-way Analysis of Variance (ANOVA) was used to test if there were significant differences in the number of images of medium-large predators along the park's boundary between the cells. A Chi-square test of independence was used to determine if there were significant differences in the number of intensively use holes between the divisional cells.

4.3.2 Camera trap survey: Occupancy of medium-large predators

Images downloaded from each camera were entered into the Camera Base 1.3 software which was used to manage and analyze images. Camera Base arranges data according to the list of species photographed at each camera station in relation to the date and time at which images of species were recorded. Survey effort was calculated as the number of camera traps multiplied by the number of sampling unit/camera days (Rovero *et al*. 2010). For the purpose of this study a sampling unit was considered to be one monitoring day (24-hours) from 24:00 to 23:59. Camera trap days were expressed as the total number of days each camera was active. Images from one camera station were deemed independent only if images of the same species occurred more than 30 minutes apart (O'Brien *et al.* 2003; Jenks *et al.* 2011). Missing camera days that resulted from animal interference, camera malfunction or batteries running out in areas of high animal movements such as water points were excluded from the data analysis.

Using Camera Base the images from each camera station were organized into a 'detection history'. Binary values of ''1'' and ''0'' were used to describe the detection of a species at each camera with '1' representing species detection and '0' representing no-detection (MacKenzie & Royle 2005). As the aim of the camera trap study was to investigate predator occupancy, and not the number of individuals of each predator species, I used the single-species-single-season occupancy model to analyze the estimates of species occupancy and probability of detection rates (MacKenzie *et al*. 2002). Unlike other mark-recapture analyses, this model does not require identification of individuals of a species but rather focuses on the occurrence of the species of interest across the selected study site (MacKenzie *et al*. 2002). Analyses for occupancy were conducted using the PRESENCE program version 11.5. The program generates estimates of maximum likelihood required for determining species occupancy (Ψ) and probability of detection (p) (MacKenzie *et al*. 2002; MacKenzie *et al*. 2006).

4.3.3 Spoor density as a measure of predator species' habitat preference

Spoor density and spoor frequency were calculated in accordance with Stander (1998), where spoor density is defined as the number of spoors encountered per 100km (Stander 1998). In other words, *x* number of spoors is expected to be encountered after 100km of spoor tracking. Spoor frequency was defined as the number of km per spoor.

The number and length of transects were related to an index (penetration) of the size of the study area to indicate sampling effort. The penetration rate is defined as the sum of combined transect distances expressed as a ratio of 1km x km^2 surface area of the study area (Stander 1998). The one-way Univariate Analysis of Variance (UNIANOVA) was used to determine if there was a significant difference in the medium-large predator species spoor densities.

A one-way ANOVA was used to test if there were statistically significant differences in predator spoor density and abundance between the four cells (C1-C4) of the reserve. Data were tested for normality using the Komogorov-Smornov two-sample test. All statistical tests were performed using the Statistical Package for Social Sciences (SPSS) Version 24 and statistical significance was set at the 95% CL.

The utilization of each of the available habitats based on spoor counts was investigated in accordance with Neu *et al*. (1974) which uses a Chi-square goodness-of-fit test to determine if habitat utilization is in proportion to the availability of habitats. If significance is detected, Bonferroni confidence intervals are generated to indicate which habitats are considered to be preferred, avoided or utilized as expected. The following formula was used to calculate confidence intervals where $\bar{p}_i$ is the proportion of predators' spoors in each habitat type, n is the sample size expressed as the number of spoors observed within each habitat.

$$\bar{p}_i - z_{(1-a/2k)}\sqrt{\bar{p}_i(1-\bar{p}_i)/n} \qquad \leq p_i \leq \bar{p}_i + z_{(1-a/2k)}\sqrt{\bar{p}_i(1-\bar{p}_i)/n}$$

4.4 Results

4.4.1 Characterisation and utilization of holes along boundary fence

During the boundary fence survey, 128 holes were recorded (south-east cell, n=39; south-west cell, n=37; north-west cell, n=29 and north-east cell, n=23), hole density was calculated at 0.64 holes/km. Based on the Chi-square test of independence results, there was no significant difference in the number of intensively used holes between the four cells (X^2 = 12.00, p = 0.213).

Table 4.2 Categorized holes distribution within the divisional cells based on the utilization score

		Cell				
Category	**Utilization Score**	**North-west**	**North-east**	**South-east**	**South-west**	**Total**
Intensively used	**1**	12	0	8	33	53
Moderately used	**2**	9	8	9	2	28
Less intensively used	**3**	8	15	22	2	47
Total		29 (23%)	23(18%)	39 (30%)	37 (29%)	128

The highest number of 'intensively used' holes was recorded in the south-west cell (n=33) and the lowest in the north-east cell (n=0). Less intensively used holes occurred mostly in the south-east cell (n=22) and least in the north-west cell (Table 4.2). The distribution of holes along the perimeter fence is shown of Figure 4.7.

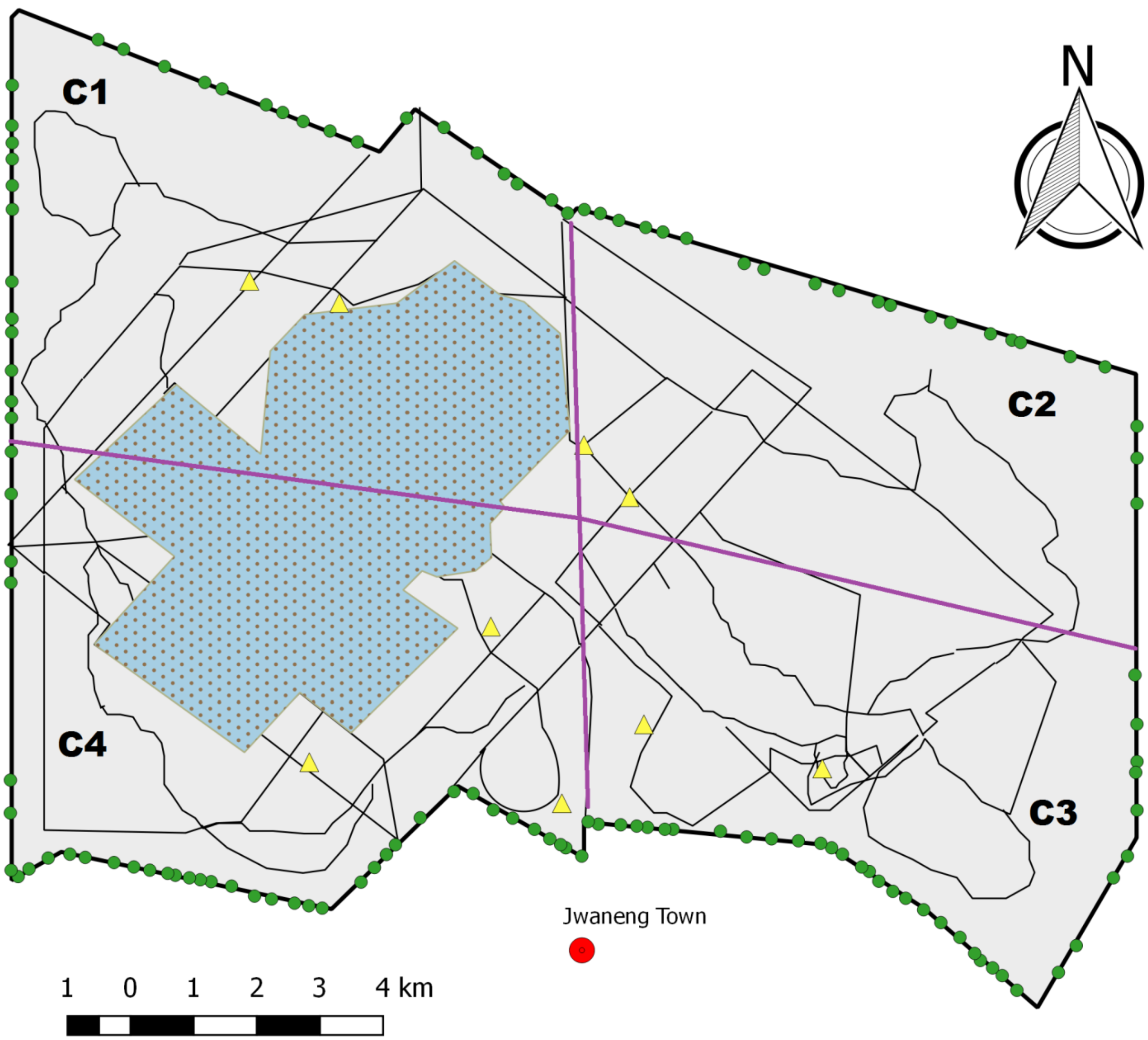

Figure 4.7 Distribution of holes (green dots) beneath Jwana Game Park's boundary fence, park roads (black lines), water points (yellow triangles) and the four divisional cells (C1-C4).

A total of 185 independent images of medium-large predators were recorded from the eight camera stations along JGP's perimeter fence during the sampling period. Predator species identified in the images included brown hyena, jackal, caracal, leopard and Cape fox (Table 4.3).

Of the 185 images 57% (n=105) were recorded in the north-east cell, 35% (n=64) in the south-west cell, 5% (n=10) in the north-west cell and 3% (n=6) in the south-east cell. Jackal and brown hyena were recorded at seven (88%) of the eight camera sites, whereas Cape fox and caracal occurred at five (63%) and four (50%) stations respectively. Leopard was recorded at two (25%) camera stations. The One-way Analysis of Variance (ANOVA) indicated significant differences in the number of independent captures of medium-large predators along the parks' boundary between the cells (F (3, 16) = 4.740, p = 0.015). A Tukey post-hoc test indicated significant differences between the north-west and north-east cells (p = 0.027) and between the north-east and south-east cells (p = 0.021).

Table 4.3 Number of images captured for each medium-large predator species at holes along the perimeter fence in relation to the divisional cells of Jwana Game Park.

	Cell				
Species	**North-west**	**North-east**	**South-east**	**South-west**	**Total**
Jackal (*Canis mesomelas*)	1	45	6	32	84
Brown hyena (*Hyaena brunnea*)	5	35	0	10	50
Cape fox (*Vulpes chama*)	1	3	0	12	16
Leopard (*Panthera pardus*)	3	6	0	1	10
Caracal (*Caracal caracal*)	0	16	0	9	25
Total	10	105	6	64	185

The majority of jackal events (54%; n=45) were captured in the north-west cell. Brown hyena was captured mostly in the north-east cell (n=35; 70%) whereas no images of brown hyena were captured in the south-east cell (n=0) (Table 4.3). Most (60%; n=6) of the leopard's capture events took place in the north-east cell (Table 4.3).

4.4.2 Camera trap survey: Occupancy of medium-large predators

The camera trap survey took place from February to December 2015, during which 3860 images were captured, comprising 21 mammal species (Table 4.4). Cameras were operational for 2197 camera trap days of a potential 2324 camera trap days. On average cameras recorded about 1.8 independent images per camera trap day.

Table 4.4 Number of images and capture frequency (number of images/1000 trap days) for all species recorded during camera trap survey

Common	Species	No. of independent images	Total no. of images	Species capture frequency	No. of camera stations at which species was recorded
Aardvark	*Orycteropus afer*	22	22	36.79	10
Jackal	*Canis mesomelas*	140	149	246.12	25
Blue wildebeest	*Chonnochaetes taurinus*	463	981	846.68	22
Brown hyena	*Hyaena brunnea*	131	131	218.19	23
Cape fox	*Vulpes chama*	37	38	65.21	11
Caracal	*Caracal caracal*	52	55	88.76	10
Cheetah	*Acinonyx jubatus*	2	2	3.46	2
Common duiker	*Sylvicapra grimmia*	16	18	26.84	8
Eland	*Taurotragus oryx*	628	2047	1107.14	27
Gemsbok	*Oryx gazelle*	500	831	850.96	28
Giraffe	*Giraffa carmelopadalis*	231	354	418.42	21
Impala	*Aepyceros melampus*	372	1589	646.83	16
Kudu	*Tragelaphus strepsiceros*	113	184	194.05	19
Leopard	*Panthera pardus*	99	121	173.2	18
Red hartebeest	*Alcelaphus buselaphus caama*	401	884	718.44	26
Springbok	*Antidorcus marsupialis*	78	254	138.28	8
Steenbok	*Raphicerus campestris*	184	195	337.54	23
White rhino	*Ceratotherium simum*	54	111	104.73	9
Wild cat	*Felis silvestris*	11	12	18.61	6
Wild dogs	*Licaon pictus*	1	3	1.73	1
Zebra	*Equus zebra zebra*	324	2009	601.66	17
Total		3860	9991		

Of the 3860 images captured, 462 (12%) were of medium-large predators constituting 5% (n=499) of all the animals captured during the survey (Table 4.4). Jackal was the most commonly photographed predator species with 140 images captured at 25 of the 28 camera stations thus constituting 30.3% of predator images (Figure 4.8). Brown hyena was identified in 131 (28.4%) images taken at 23 sites and leopard in 99 (21.4%) images taken at 18 sites (Figure 4.8). Cheetah and wild dogs constituted only 0.4% (2) and 0.2% (1) of the images respectively.

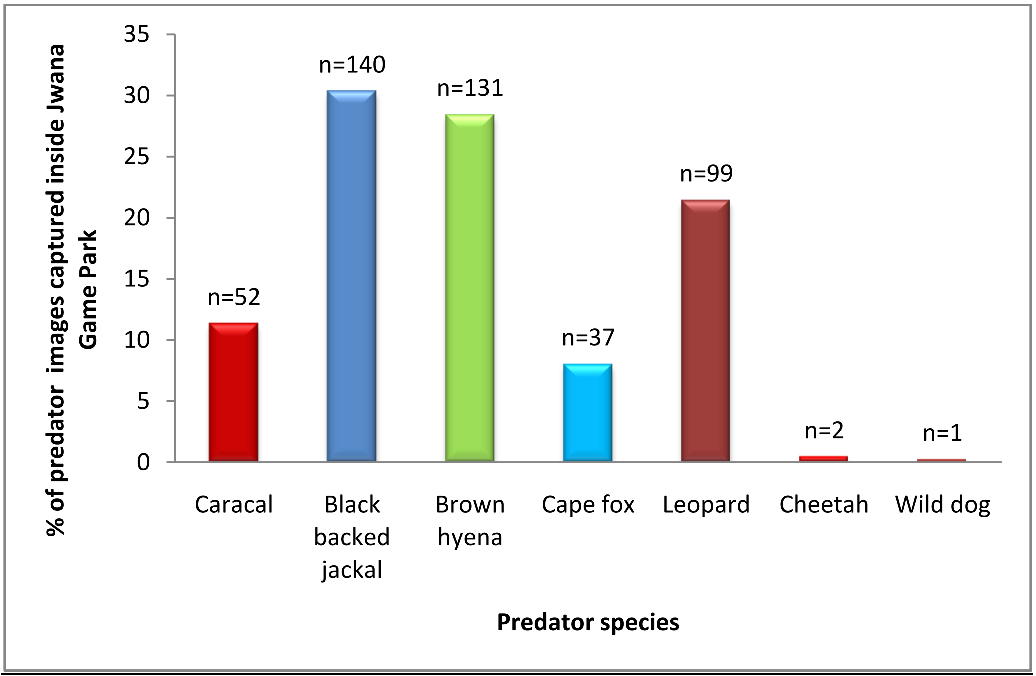

Figure 4.8 Images captured for each predators species during camera trap survey (n=462), y-axis represent percentage contribution of each species.

4.4.2.1 Predator species occupancy estimate

Detection probabilities for predators varied between species. Jackal had the highest detection probability (7%) followed by leopard (6%) and brown hyena (5%). Caracal, cheetah, Cape fox and wild dog had a low detection probability estimate (≤0.03) which is an indication of low detection ability or a very low population density in the study area (Figure 4.9).

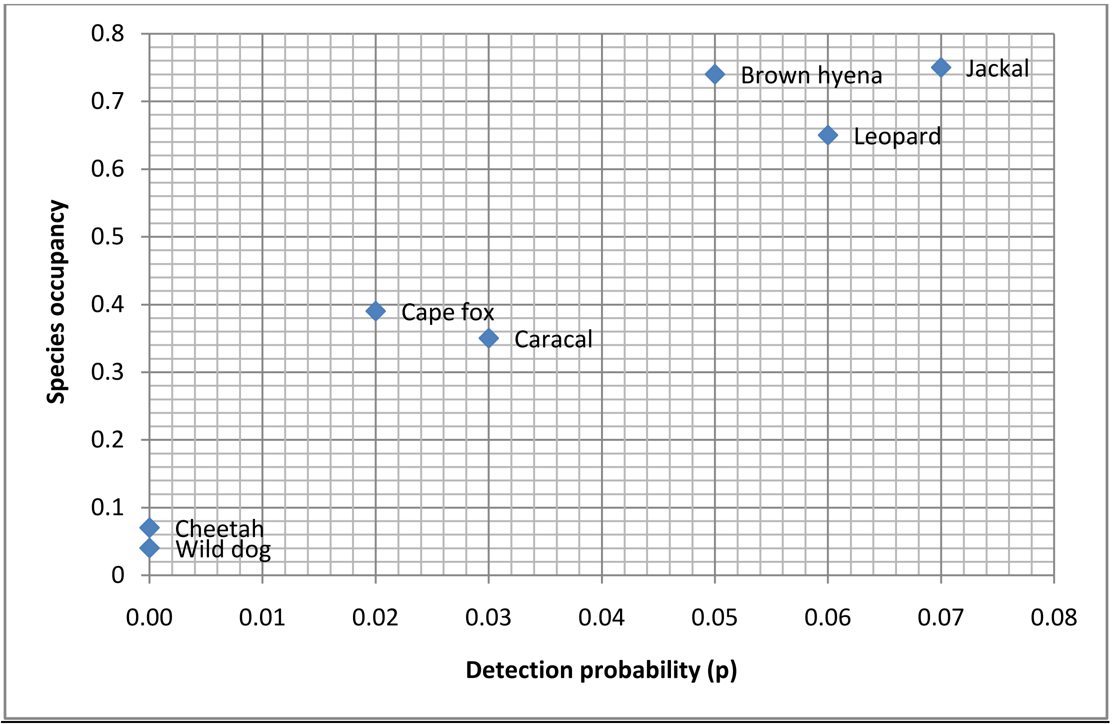

Figure 4.9 Predator species occupancy estimates and detection probability based on camera trap images during the study period on Jwana Game Park.

Results from the single species, single season occupancy model indicated occupancy estimates for identified medium-large predators as follows: caracal (Ψ = 0.35 ± 0.00), Cape fox (Ψ = 0.39 ±0.00), leopard (Ψ = 0.65 ± 0.09), brown hyena (Ψ = 0.74 ± 0.08) and jackal (Ψ = 0.75 ± 0.09). Due to the extremely low detection probabilities for cheetah and wild dog (p = 0.00), the model could not assess occupancy estimates for these two species.

4.4.2.2 Comparison of species occupancy between divisional cells

The results from the single species, single season occupancy model indicated that the highest brown hyena occupancy estimate was Ψ =1.00 ± 0.00 in both the north-east and the south-east cell. The south-west cell had an occupancy estimate of Ψ = 0.86 ± 0.13 while the north-west cell had the lowest estimate of brown hyena occupancy (Ψ = 0.60 ± 0.20). Contrary to this, the leopard occupancy estimate was higher in the north-west cell ($\Psi = 1.00 \pm 0.00$) and lowest in the north-east cell $\Psi = 0.57 \pm 0.19$. The south-east cell indicated leopard's occupancy estimate of $\Psi = 0.86 \pm 0.13$ while the south-west cell had an estimate of $\Psi = 0.58 \pm 0.19$. The occupancy estimate for jackal was higher in the south-eastern and north-western cells ($\Psi = 1.00 \pm 0.00$ each) than in the south-west cell ($\Psi = 0.43 \pm 0.19$). The north-east cell had an occupancy estimate of $\Psi = 0.86 \pm 0.13$ for jackal (Table 4.5).

The highest estimate of occupancy for caracal was estimated in the north-east ($\Psi = 0.72 \pm 0.17$) cell after being detected at five of the seven camera stations. The south-east cell suggested an occupancy estimate of $\Psi = 0.58 \pm 0.19$ for caracal after being detected at four camera stations (Table 4.5). The south -west cell had the lowest occupancy estimate ($\Psi = 0.14 \pm 0.13$) for caracal where it was detected at only one camera station. No caracal was recorded by cameras in the north-west cell. Cape fox had the highest occupancy estimate in the north-west cell ($\Psi = 0.70 \pm 0.26$) being detected at four camera stations. The north-east and south-east cells had equal occupancy estimates for Cape fox ($\Psi = 0.43 \pm 0.19$), which was detected at three camera stations in each of these two cells. The occupancy estimate for Cape fox in the south-west cell was lower than in the north-east and south-east cells ($\Psi = 0.18 \pm 0.18$) where detection was only at one camera station. Owing to their low detection rates, occupancy estimates for cheetah and wild dogs could not be calculated. However, cheetah was recorded at two camera stations and wild dogs at one camera station (Table 4.5).

Table 4.5 Species occupancy (Ψ) estimates (proportion of cell occupied by species) within the different cells, detection probabilities (p) and species capture frequencies (No. of captures/1000 camera days) for species at the different camera trap stations. NW: north-west cell, NE: north-east cell, SE: south-east cell, SW: south-west cell

Cell	Species	Detection probability (p)	Species Occupancy (Ψ)	Standard Error	95% confidence Interval	Species capture frequency at camera stations	No of camera trap stations detected
NW	Brown hyena	0.04	0.60	0.20	0.23-0.88	28.30	4
NW	Leopard	0.01	1.00	0.00	0.00-1.00	12.10	4
NW	Jackal	0.02	1.00	0.00	0.00-1.00	18.20	5
NW	Caracal	0.5	0.00	0.00	0.00-1.00	0.00	0
NW	Cape fox	0.02	0.70	0.26	0.17-0.96	18.20	4
NW	Cheetah	-	0.00	0.00	0.00-1.00	0.00	0
NW	Wild dogs	-	0.00	0.00	0.00-1.00	0.00	0
NE	Brown hyena	0.08	1.00	0.00	0.00-1.00	85.70	5
NE	Leopard	0.1	0.57	0.19	0.23-0.86	66.70	4
NE	Jackal	0.1	0.86	0.13	0.42-0.98	96.80	6
NE	Caracal	0.06	0.72	0.17	0.31-0.93	42.90	5
NE	Cape fox	0.05	0.43	0.19	0.14-0.77	22.20	3
NE	Cheetah	-	-	0.00	0.00-1.00	0.00	0
NE	Wild dogs	-	-	0.00	0.00-1.0	1.70	1
SE	Brown hyena	0.07	0.86	0.13	0.42-0.98	65.70	6
SE	Leopard	0.58	0.86	0.13	0.41-0.20	51.90	6
SE	Jackal	0.06	1.00	0.00	0.0-1.00	62.30	7
SE	Caracal	0.05	0.58	0.19	0.23-0.87	27.70	4
SE	Cape fox	0.05	0.43	0.19	0.14-0.77	20.80	3
SE	Cheetah	-	-	0.00	0.00-1.00	3.50	2
SE	Wild dogs	-	-	0.00	0.00-1.00	0.00	0
SW	Brown hyena	0.03	1.00	0.00	0.02-0.05	34.60	6
SW	Leopard	0.06	0.58	0.19	0.23-0.86	38.30	4
SW	Jackal	0.1	0.43	0.19	0.14-0.77	60.10	3
SW	Caracal	0.07	0.14	0.13	0.02-0.58	16.40	1
SW	Cape fox	0.02	0.18	0.18	0.02-0.71	3.60	1
SW	Cheetah	-	-	0.00	0.00-1.00	0.00	0
SW	Wild dogs	-	-	0.00	0.00-1.00	0.00	0

4.4.3 Spoor density as a measure of predator species' habitat preference

During the spoor survey, each of the seven transects were sampled 22 times and their combined daily distance per survey was 62.81 km (Table 4.6).

Table 4.6 Summary of daily and monthly distances covered during spoor surveys along the seven transects within Jwana Game Park. Information is based on two surveys per month over the eleven month survey period.

Transect	Daily Survey Distance (km)	Monthly Survey Distance (km)	Total Survey Distance (km)
1	7.32	14.64	161.04
2	7.48	14.96	164.56
3	13.82	27.64	304.04
4	8.52	17.04	187.44
5	9.57	19.14	210.54
6	8.62	17.24	189.64
7	7.48	14.96	164.56
Total	**62.81**	**125.62**	**1381.82**

Five medium-large predator species were identified during spoor surveys and included brown hyena, leopard, jackal, cheetah and caracal. From the 22 surveys of each transect over the 11 month study period, 602 spoors were identified and recorded. Of these 602 spoor, 354 (58.9%) were of brown hyena, 140 (23.3%) of leopard, 88 (14.6%) of jackal, 10 (1.6%) of cheetah and 10 (1.6%) of caracal (Table 4.7). No wild dog spoor was located during the surveys.

Table 4.7 Results of the medium-large predator spoor survey in Jwana Game Park, road penetration is the sum of combined survey transects expressed as a ratio of 1km to x km^2 surface area to indicate sampling effort.

Total area (JGP) (km^2)	157.00					
Road penetration	2.50		Estimates per cell			
	Estimates for the park		NW	NE	SE	SW
Total survey distance (km)		1381.82	377.85	265.21	367.29	371.47
Total number of spoor		**602**	128	126	168	180
Number of spoor per species	Brown hyena	354	64	63	109	118
	Leopard	140	29	35	33	43
	Jackal88		31	23	19	15
	Caracal	10	4	3	3	0
	Cheetah	10	0	2	4	4
Spoor density (no. spoor per 100 km)	Brown hyena	25.62	16.94	23.75	29.68	31.77
	Leopard	10.13	7.68	13.20	8.98	11.58
	Jackal6.37		8.20	8.67	5.17	4.04
	Caracal	0.72	1.06	1.13	0.82	0.00
	Cheetah	0.72	0.00	0.75	1.09	1.08
Spoor frequency (no. of km per spoor)	Brown hyena	3.90	5.90	4.21	3.37	3.15
	Leopard	9.87	13.03	7.58	11.13	8.64
	Jackal	15.70	12.19	11.53	19.33	24.76
	Caracal	138.18	94.46	88.40	122.43	0.00
	Cheetah	138.18	0.00	132.61	91.82	92.87

4.4.3.1 Species spoor density

Results from the Univariate Analysis of Variance (UNIANOVA) indicated a statistically significant difference between species spoor density in JGP (F (4, 45) = 50.390, p = 0.00). However, pairwise comparisons found no significant differences in spoor densities between cheetah and caracal (MD = 0.091, p = 0.641), jackal and cheetah (MD = 0.339, p = 0.086) and leopard and jackal (MD = 0.342, p = 0.083).

One-way ANOVA results indicated no statistically significant differences between the different divisional cells within species, (F (3, 16) = 0.081, p = 0.969). In terms of spoor frequency, the UNIANOVA test results indicated a statistically significant difference in mean medium-to-large predators (F (4, 15) = 4.608, p = 0.013). Brown hyena had the highest spoor frequency of 3.90km/spoor followed by leopard with 9.87km/spoor. Spoor frequency for jackal was 15.70km/spoor. The Pair-wise test indicated that the mean spoor frequency for brown hyena was significantly different from those of caracal (MD = -72.165, p = 0.013) and cheetah (MD = -75.168, p = 0.08) (Table 4.9). Pairwise tests also indicated that leopard spoor frequency was significantly different from those of caracal (MD = -66.228, p = 0.016) and cheetah (MD = -69.230, p = 0.013). Jackal also had a statistically significant difference in the mean spoor frequency compared to caracal (MD = -59.370, p = 0.029) and cheetah (MD = -62.373, p = 0.022). The highest significant differences in mean spoor frequency occurred between brown hyena and cheetah (MD = 75.161, p = 0.008) followed by leopard and cheetah (MD = 69.230, p = 0.013).

4.4.3.2 Habitat utilization

The results of the chi-square Goodness-of-fit test indicated a significant difference in total predator spoor abundance between grassland and bush-land habitats $\chi^2 = 65.9$, $p<0.05$. However, there was no significant difference in cheetah and caracal spoor abundance between the two habitats (Table 4.8).

Table 4.8 Chi square Goodness-of-fit test results of medium-large predator species habitat utilization between grassland and bush-land habitats. Significance level is set at α= 0.05

Species	χ^2 test statistic for comparison between habitats
Brown hyena (*Hyena brunnea*)	$\chi^2 = 40.677$, $p<0.05$
Jackal (*Canis mesomelas*)	$\chi^2 = 18.689$, $p<0.05$
Leopard (*Panthera pardus*)	$\chi^2 = 14.727$, $p<0.05$
Caracal (*Caracal caracal*)	$\chi^2 = 2.778$, $p = 0.096$
Cheetah (*Acinonyx jubatus*)	$\chi^2 = 0.200$, $p = 0.655$

The generated Bonferroni confidence intervals suggested that brown hyena, leopard and jackal exhibited preference for the grassland habitat but avoided the bush-land habitat areas. Caracal and cheetah utilized both habitats in proportion to their availability (Table 4.9).

Table 4.9 Predator occurrence within Jwana Game Park in relation to different habitats, preference and/or avoidance of different habitats by predator species is shown

Habitat	**Habitat Size (ha)**	**Proportion of total hectares (pio)**	**Species**	**Number of spoor observed (n)**	**Proportion of spoor observed (pi)**	**Number of spoor expected (prop ha*n)**	**Confidence interval on proportion of occurrence (95% confidence coefficient)**	**Species habitat preference/avoidance**
Grassland	7614.5	0.42	Brown hyena	251	0.664	157	0.611 ≤ pi≤ 0.717	Preferred
			Leopard	119	0.661	67	0.583 ≤ pi1 ≤ 0.739	Preferred
			Jackal	62	0.705	33	0.598 ≤ pi ≤ 0.812	Preferred
			Caracal	2	0.222	3	0.083 ≤ pi ≤ 0.527	Used as expected
			Cheetah	9	0.45	7	0.205 ≤ pi ≤ 0.695	Used as expected
Bushland	10704.7	0.58	Brown hyena	127	0.336	197	0.283 ≤ pi ≤ 0.389	Avoided
			Leopard	61	0.339	94	0.261 ≤ pi ≤ 0.417	Avoided
			Jackal	26	0.295	46	0.188 ≤ pi ≤ 0.402	Avoided
			Caracal	7	0.778	5	0.473 ≤ pi ≤ 1.083	Used as expected
			Cheetah	11	0.55	10	0.305 ≤ pi≤ 0.795	Used as expected
Total	**18319.2**	**1**		**675**				

Proportion of total hectares (pio) = proportion of expected predator spoor observation as if occurrence of predators in each habitat was proportional to the habitat's availability in terms of size.

4.5 Discussion

4.5.1 Camera trap survey: Occupancy of medium-large predator

Occupancy models have been used to study predators by researchers in protected areas across the globe (Hames *et al*. 2001; Mackenzie *et al*. 2002; Mackenzie & Nichols 2004; Bailey *et al*. 2007; Thorn *et al*. 2009; Tilker 2014; Pacifici *et al*. 2016). The results of my study reaffirm the suitability of using camera traps in data collection for elusive mammalian species. The occupancy model was used in this study as a substitute to abundance (MacKenzie & Nichols 2004) in estimating medium-large predator occurrence within JGP. Although the study did not examine the covariates of species occupancy (such as water point locations and nearest cattle posts), it still provides some valuable information on the proportion of the park occupied by medium-large predators and potential conservation implications.

During the survey, seven medium-large predator species were detected inside the park. The overall average predator occupancy for medium-large predators in my study was estimated at $\Psi = 0.43$ and differed slightly to those of Lisek (2013) who estimated the overall average occupancy for medium-large predators at $\Psi = 0.55$ in Northern Tuli Game Reserve. Occupancy estimates varied between species with brown hyena, jackal and leopard estimated at ≥ 0.65. The occupancy estimate for Cape fox and caracal was estimated at $\Psi \leq 0.39$. Due to their low detection probability ($p = 0.00$), occupancy data for cheetah and wild dog could not be analyzed by the model. However, previous studies found occupancy estimates of $\Psi = 0.40$ for cheetah in Limpopo National Park (Andresen *et al*. 2014), whereas caracal indicated a naive occupancy estimate of $\Psi = 0.61$ in another study at Ranthambhore Tiger Reserve in Western India (Sigh *et al.* 2015).Variation of predator occupancy in protected areas is attributed to intra-guild species interactions and resource availability (Schuette *et al*. 2013; Rich *et al*. 2017), which often results in subordinate predators exhibiting avoidance of niche sharing with top predators as a way of minimizing competition (Hayward & Slotow 2009). These observations are supported by the findings of my study because predators such as brown hyena appeared to be in avoidance of sections of JGP that were occupied by apex predators such as leopards. Predator occupancy estimates in relation to occurrence of other predators within the different sections of the park are discussed in the following sections. In addition to habitat loss (Marker & Penzhorn 1998), cheetah and wild dog population decline is influenced by exploitation and interference competition that results from an increase in numerical abundance of dominant competitors (Hayward & Kerley 2008).

4.5.1.1 Comparison of predator occupancy between cells

Although brown hyena had the highest occupancy estimate in the park, my study indicated that the highest occupancy estimate for brown hyena was in the north-eastern and south-eastern cells. In contrast, the leopard occupancy estimate was higher in the north-west cell which had the lowest occupancy estimate for brown hyena. Furthermore, leopards' occupancy estimate was lower in the north-eastern cell, the same cell which had the highest occupancy estimate for brown hyena. There is limited information to support these findings, as such; there is need for further investigations to substantiate factors that could have influenced this avoidance of niche sharing by brown hyena and leopard. In some cases, avoidance of niche sharing can be influenced by factors such as apex-subordinate species competition (Hayward & Slotow 2009).

Jackal occurred mostly in the north-west, north-east and south-east cells. The south-west cell is situated closer to Jwaneng town which has high human habitations and movement. The cell is also close to the Trans Kalahari highway which has a high volume of motor vehicles most of which are cargo carriers that transport the goods from South Africa to neighboring countries like Namibia and Angola. However, the low occurrence of jackal in the south-west cell could be due to avoidance of human induced disturbances that are common in the area.

Caracal occurred more frequently in the north-east side of the game park, than in the south-west cell where the occupancy estimate for caracal was relatively low. However, caracal occupancy in the south-west cell was higher than the north-west cell where no caracals were recorded. These results suggest that caracal avoided the areas of the park with high leopard occupancy. This could be an act of avoiding the possible risk of injuries and/or mortality by leopards as was the case in the study of Martins (2010) where leopards were observed attacking and sometimes killing caracals. Caracals further appeared to coexist with non-apex predators such as brown hyena and jackal possibly due to reduced risks of attack. The findings align well with those of Pringle & Pringle (1979) who found a balanced two-way direction of inter-specific competition between caracal and jackal. In the Kgalagadi Transfontier Park, caracal was recorded attempting to predate on jackal although the hunt was not successful (Melville *et al*. 2004). Jackal was however found to make up 0.3% of the prey composition in the diet of caracals (Melville *et al*. 2004), a potential factor that could have influenced an abundance of jackals in areas with high occupancy of caracal. Jackals have also been reported to hunt and kill caracal kittens especially when mothers were not present at the den (Pringle & Pringle 1979). In addition to jackal, Cape fox was hunted in 3.1% (n=10) of caracal's interspecies hunting occasions in the Kgalagadi

Transfontier Park and was found to constitute 4.3% of prey composition in the diet of caracal (Melville *et al*. 2004). It is therefore not surprising that the highest occupancy for Cape fox was estimated in the north-west cell, the same cell that had the lowest occupancy estimate for caracal.

There could be other ecological factors that influence the occurrence of species within the different divisional cells. High predator occupancy for most predators (brown hyena, leopard, jackal, caracal and Cape fox) in the north-west cell could be associated with the existence of the cattle ranches which are situated outside the northern sections of the park and the cattle posts outside the western section of the park. In addition, the north and the western parts of the park appear to have less adjacent anthropogenic impacts in the form of human settlements compared to other parts thus possibly being the only available habitats that could be used by these species to expand their home ranges outside of the park. Anthropogenic activities have the potential to regulate predator populations as predators tend to avoid areas with high human activities for reasons such as possible human persecution (Colyn *et al*. 2004) or hunting in retaliation to perceived or real threats to livestock (Treves & Karanth 2003). Naturally predators avoid areas with high levels of human activity sometimes to a point where even non-lethal practices such as pastoralism and tourism can influence their occurrence and viability (Reed & Merenlender 2008).

4.5.1.2 Comparison of species capture events at the park boundaries of divisional cells

The number of predator capture events at the boundary fence suggests that there is frequent animal movement between the park and adjacent farmlands. However, the intensity of this movement varied among the different cells with the majority of species moving though the north-east cell boundary except for Cape fox which was mostly captured along the south-west cell boundary. The species which had the highest movement events through the north-east cell boundary were brown hyena and jackal followed by caracal and leopard. These findings do not support my second prediction that predator capture events at the boundary fence would be higher in the cell with a high number of intensively used holes. Although the north-east cell had the highest number of capture events (n = 105; 57%), this cell had no holes with signs of frequent animal movements. The majority (n = 15; 65%) of holes along the fence in the north-east cell were less intensively used and only 35% (n = 8) were moderately used. Further studies are required to investigate factors that influence occupancy and hole use in this section of the game park. The movement of predators through the park boundary to the neighboring farmlands could therefore be linked to factors such as the size of the game park which is arguably small to meet some of predators' ecological requirements such as home ranges (Hansen & DeFries 2007; Newmark 2008). Inter-species competition for limited resources is another important factor which has the aptitude to affect predator population dynamics within protected areas (Carbone *et al*. 1997, Sinclair *et al.* 2003; Hayward & Kerley 2008). Competition is more prevalent when a dominant species interacts with less competitive and more inferior species (Palomares & Caro 1999) forcing them out of the boundaries of protected areas. The land that is situated adjacent to the north-east of JGP is predominantly used for pastoral farming at both the commercial and subsistence levels. Therefore, the movements in and out of JGP demonstrated by predators imply that there is potential predator-livestock interaction that may translate into incidents of livestock depredation.

4.5.2 Spoor density as a measure of predator species' habitat preference

The distribution of predator spoors differed significantly between the species inside JGP. Brown hyena spoor were very closely distributed (clumped) across the park as opposed to those of leopard and jackal which were more distributed. Furthermore, spoor densities also differed significantly between predator species with brown hyena appearing as the most abundant medium-large predator species. Over a period of seven years (2008-2015) cheetah spoor density in Jwana Park decreased from 2.32 cheetah spoor density per 100km (Houser, 2008) to an estimate of 0.72 cheetah spoor per 100km (my study). However, leopard spoor density increased from 0.15 leopard spoors per 100km (Cheetah Conservation Botswana 2006) to 10.13 leopard spoor per 100km. This suggests that the cheetah population in JGP has decreased whereas the leopard population has increased. While the reasons for apparent population changes could not be qualified through my study, previous studies have demonstrated similar influences in some areas where leopards attacked and killed cheetah (Kruuk & Turner 1967; Schaller 1972; Mills 1990; Laurenson 1995), a factor that could ultimately result in cheetah on JGP avoiding habitats with high occupancy of leopards (Hayward & Kerley 2008). The spoor density for brown hyena did not change much from the previous 15.42 brown hyena spoor per 100km (Cheetah Conservation Botswana 2006) compared to my study where an estimated 16.94 brown hyena spoors per 100km was calculated.

Although predator spoor densities differed significantly between species inside the park, densities indicated no significant differences when compared between species among the different cell divisions in the park. This implies that different predator species occurred in all sections of the park even though they varied in abundance. This could be due to the size of the park which is relatively small thus allowing predators to move across the park without being limited by the distance they have to cover to reach the other side, thus the high occupancy levels for most of the predators identified in this study

Most animal species exhibit some degree of preference or avoidance in habitat use with only a few being able to make use of available habitats proportionally (Abramsky *et al*. 2002). Preference or avoidance is often dependent on the ecological requirements of a species within different habitats coupled with the ability to adapt to various interactions with both the abiotic environment and other species present. Habitat utilization should therefore occur as a function of balancing the benefit with the risk of selecting such a habitat (Abramsky *et al*. 2002). In general, predator species use different tactics to deal with the risk of intra and inter-predator interactions posed by competitors, which includes selection of habitats with low risk of predation termed 'predator refuge' (Durant 1998) or altering their habitat use or anti-predator behavior in order to align with changing levels of risk (Creel *et al*. 2001). Such reactions to risk can either be reactive where an animal avoids encounters with other predators based on the knowledge of actual risk or predictive where the animal identifies a potential risk based on the past knowledge of the presence of predators in one particular area (Broekhuis *et al*. 2013).

In the context of this study, the two available habitat types on JGP differed in terms of their utilization by predators with preference given to grassland despite its smaller size in comparison to the abundant bush land habitat. The disproportional distribution of medium-large predators within different habitats of JGP is attributed to abundance of small to medium sized herbivores. At the time of sampling most of the small to medium sized herbivores such as steenbok, impala, springbok and blue wildebeest were observed in the grassland compared to the bush land habitat (Figure 4.10), which is where they are expected to be found as they are mainly grazers. These prey species are considered in many studies to be the preferred size of prey for these predators (Hayward *et al*. 2006). However, having said this due to detection of small herbivores in the bushland areas being lower than would be for more open grassland habitats, it is also possible that the numbers of herbivores in the bushland area is underestimated.

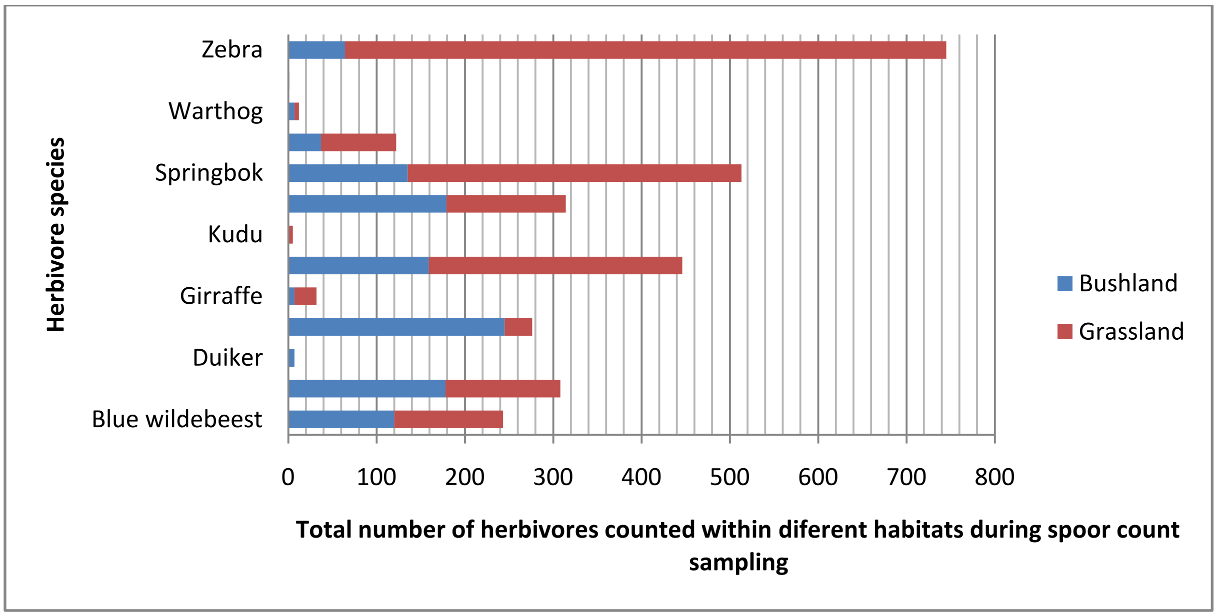

Figure 4.10 Number of herbivore species counted and added together throughout the duration of the spoor count sampling period

My findings concur with previous studies that associated predator habitat selection to prey abundance (Laurenson 1995; Stander *et al*. 1997; Marker & Dickman 2005; Hayward *et al*. 2017; Burton *et al*. 2012). Regulating mechanisms such as structural variation, abundance and spatial distribution of plants have been found to contribute greatly to herbivore habitat selection (Hobbs *et al*. 2003). Most smaller-medium sized herbivores form part of the diet of many medium-predators; therefore, availability of suitable prey species in any given habitat directly influences the distribution and abundance of predator populations (Karanth *et al*. 2004). From these findings, my prediction that predator species' preference is proportional to availability and size of the parks habitats has not been met because brown hyena, leopard and jackal were found to avoid the bush-land habitat and prefer the less abundant grass land habitat which appeared to host the majority of potential prey for JGP's predator population.

4.5.3 Characterisation and utilization of holes along boundary fence

From the results of my study it was found that holes underneath the boundary fence were not specifically concentrated in any section along the fence. However, the intensity of hole utilization was found to differ within the different divisional cells along the boundary fence. Intensively utilized holes occurred mainly in the south-west and north-west cells, both of which are located close to cattle posts and ranches. Less-intensively used holes were more in the north-east and south-east cells of the park which are cells closer to villages and settlements. In addition to the high density of villages and settlements outside of the north-east and south-east sections of the park, the Trans-Kalahari highway passes along the eastern, south and south-eastern sides of the park which connects Botswana with other countries such as Namibia, Angola, South Africa and the Democratic Republic of Congo. Physical barriers such as highways can have large-scale influences on distributional patterns of mammals and sometimes ultimately on speciation (Shepard *et al*. 2008). Roads can also impede animal movements by direct mortality or through avoidance behaviour (Shepard *et al.* 2008; Weise *et al*. 2015).

4.6 Conclusion

The application of various techniques to determine predator occupancy, distribution and habitat utilization in JGP used in this study have shown to be successful. By using both camera traps and spoor counting techniques in my study, I was able to demonstrate that JGP as a protected area has a diversity of medium-large predators. My study has confirmed that JGP is occupied by at least seven medium-large predator species of which five species were detected using spoor counts while an additional two species (Cape fox and wild dog) were captured on camera traps. Similar results were found by Torrents-Tico *et al*. (2017) when comparing the two techniques in Northern Botswana. In my study, brown hyena, jackal and leopard had higher occupancy estimates compared to caracal and Cape fox. Cheetah and wild dogs had a very low detection rate and could imply low numbers of these species in JGP. Furthermore, wild dogs were recorded in JGP for the first time during my study. The cheetah population in JGP appears to have declined since a previous study, which necessitates an investigation on the conservation needs of the species taking into account probable factors that could have influenced their decline over time.

Evidence from my study further indicates that there is movement of predators between JGP and the adjacent pastoral areas through holes under the boundary fence. This movement implies that predators could interact in one way or the other with livestock that graze on the land outside the boundaries of the JGP. However, the influence of this movement on livestock predation requires further investigation and quantification.

The results of my study thus presents an opportunity for future researches to scrutinize the factors that are associated with the in/out predator movement. It is also critical to study the ecological relationships of the predators of Jwana Park to examine how they influence the abundance and distribution of one another within the park boundaries.

In general, the predictions I made at the beginning of the study were not fully supported by the findings except prediction number three. Prediction one which expected the frequency of certain predator species to be influenced by occupancy of other predators was partly supported because brown hyena and leopard exhibited avoidance of habitats which are occupied by one another. Furthermore, caracal also appeared to avoid the sections of the park with high occupancy of leopard. My second prediction that capture events at the boundary fence will be higher at the section of JGP with high number of intensively used holes was not supported due to the fact that more predator capture events occurred at the north-east cell boundary which had the lowest number of intensively used holes. My third prediction that the number of intensively used holes were more likely to occur along the boundary fence in sections of the park that are close to farmlands is supported by the findings. The majority (84%; n = 45) of the intensively used holes were found in the north-west and south-west cells which are located adjacent to commercial cattle ranches and communal cattle posts. However, these holes were not restricted to predator use only as they were also used by other animal species such as warthogs, porcupines and aardvark (*Orycteropus afer*). Lastly I predicted that predator species will use JGP's different habitats proportionately to their availability. However, the study found that predator species such as brown hyena, leopard and jackal preferred the less available grassland habitat and avoided the bush-land habitat which is larger in surface area than the grassland habitat.

Chapter 5

Farmers' perceptions of predators within the farmlands surrounding Jwana Game Park

5.1 Introduction

Many livestock farmers perceive predators as troublesome species due to their widespread behaviour of predating on domestic animals (Madden 2006). In many parts of the world livestock farmers suffer huge economic losses to predation especially subsistence farmers with little or no alternative source of income (Thirdgood *et al*. 2005). In contrast, this human-predator conflict has significantly affected predator populations across the globe (Kruuk 2002; Dickman 2010) and has resulted in the extinction of at least two predator species such as the Falkland Island wolf (*Dusicyon australis*; Macdonald & Sillero-Zibiri 2004) and thylacine (*Thylacinus cynocephalus;* Paddle 2000). It is therefore imperative for conservationists and farmers to work together to develop human-predator conflict mitigation strategies that protect both predators and farmers together with their livestock.

Many countries such as Botswana, Tanzania, Kenya and South Africa have set aside protected areas for wildlife conservation but many of these areas have limitations in providing adequate diet and home ranges for many predator species thus forcing them to disperse into the adjacent unprotected lands where they may compete with humans for resources, which ultimately results in conflict of some sort (Treves & Karanth 2003).

While evidence suggests that most protected areas are often unable to retain predator populations within their boundaries (Patterson *et al*. 2004; Ferguson & Hanks 2012), human-predator conflict is likely to exist as conflict resolution is often the responsibility of the people who live adjacent to the boarders of these protected areas (Moruthi 2005). Therefore, the ability of many farmers to regulate the extent of livestock depredation is dependent on the efficient implementation of available traditional mitigation methods. Like many other pastoral farmers in Africa, farmers in Botswana depend on livestock as their main economic activity and as such any livestock loss whether due to predators or other cause threatens individual household food and economic security as well as wealth.

The questionnaire survey was considered suitable for collecting data to determine the degree of predator- livestock conflict within communities farming on the land adjacent to Jwana Game Park. Questionnaire surveys have increasingly been used in ecology over the past few decades (White *et al*. 2005). The method is particularly useful when primary information related to people's attitudes, behaviour, opinions and awareness about specific issues is required (Marker 2003; White *et al*. 2005). Questionnaires are often used in research studies to quantify community perceptions and views towards wildlife and related benefits or impacts (Wang & Macdonald 2006; Dickman 2008). Furthermore, questionnaires are also useful where the research seeks to integrate ecological information with communities' socio-economic or political data (White *et al*. 2005). To this end, questionnaire surveys have been employed by researches across the African continent to assess human-wildlife conflict and community perceptions in order to persuade sound decision making in management and policy development (Marker 2002; Dickman, 2005; Klein 2013). Some examples of studies that used questionnaires include: Socio economic causes and perceptions of the Maasai towards livestock predation by lions in Southern Kenya (Hazzah 2006); tolerance towards large carnivores in communities surrounding Ruaha

National Park in Central Tanzania (Dickman 2008) and an assessment of the potential for coexistence between rural people and predators in the greater Kruger National Park (Lagendijk & Gusset 2008).

The objective of this chapter was to evaluate predator-livestock conflict levels, community perceptions and the use of conflict mitigation techniques among communities farming in the vicinity of Jwana Game Park. From the above objective, the following research questions were addressed:

1. What is the status of human-predator conflict in the study area?
2. Do conflict mitigation strategies used by farmers prevent livestock depredation?
3. What is the perceived contribution of JGP to human-predator conflict in the adjacent human community?

5.2 Methods

5.2. Data Collection

Data were collected in the form of questionnaires from six farmlands (study units) adjacent to JGP. These farmlands were made up of five communal cattle posts (Bodumatau, Dinonyane, Dithobane, Kome and Machana) and four cattle ranches (regarded as one unit and referred to as cattle ranches) which are located outside the northern section of JGP (Figure 5.1).

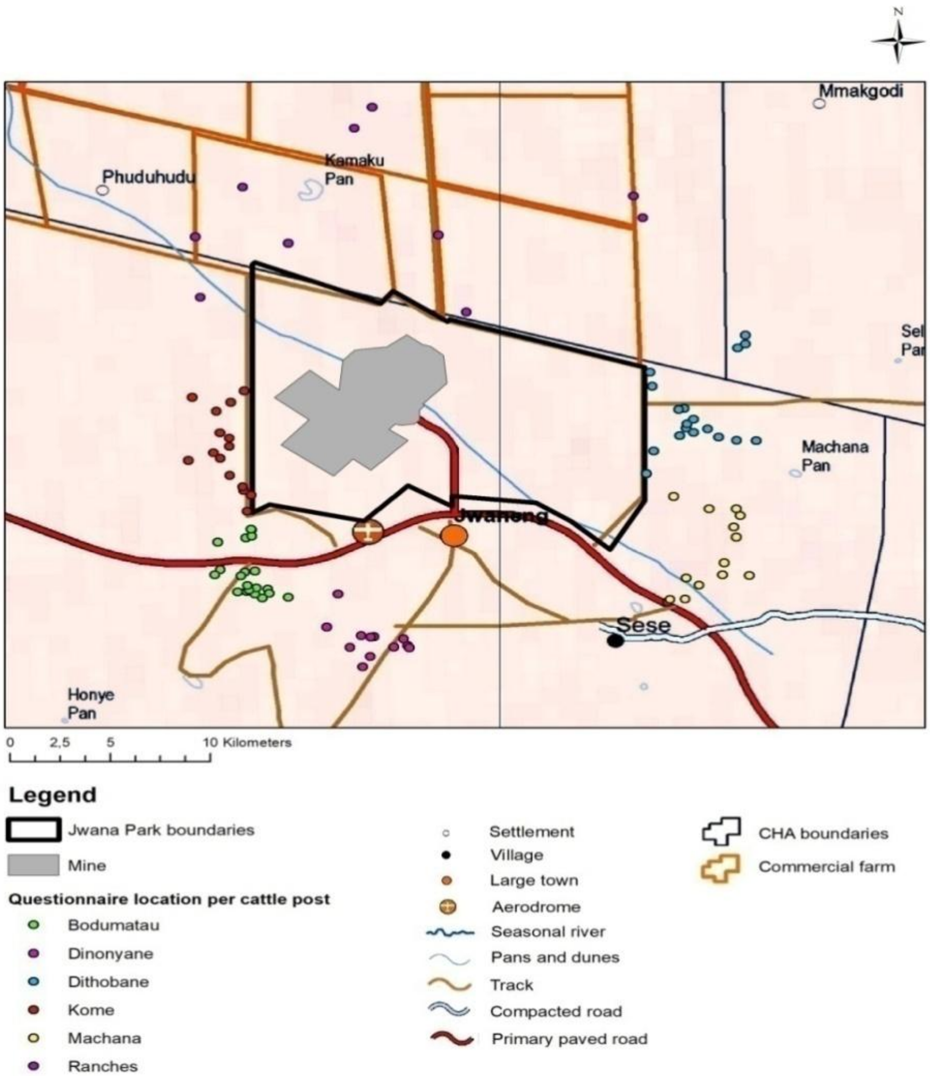

Figure 5.1 Distribution of surveyed farmlands in relation to Jwana Game Park (CHA= Controlled Hunting Area)

Interviews using face to face structured questionnaires were conducted on livestock owners and/or herders in an effort to obtain information on their perceptions and attitudes towards predators and JGP. The questionnaires (Appendix 1) had both open-ended and closed questions and were designed to allow answering of key questions that were centred on issues relating to farmers' livestock losses to predators as well as the husbandry and mitigation methods employed. Respondents were also asked questions relating to household demographics, education, livestock ownership and livestock management, number and type of livestock lost to predation, perceived predators responsible and their origin. The questionnaire was initially tested by interviewing 14 young farmers at Moleleme cattle post which is situated about 50km from the study area. This was to allow the questionnaire to be adapted for sufficient clarity and simplicity to questions that appeared confusing or difficult to answer (Klein 2013). At the time of surveying only one person who was aged 18 years or older was interviewed per selected household.

Questionnaires were presented in the local Setswana language, and only people who had been in the area for at least 12 months were interviewed. The assumption was that people who had been in the area for at least a year had enough exposure to the area and were likely to have encountered some form of human-wildlife conflict and had some exposure to predator-livestock interactions. Only one person was interviewed at a time to prevent influential opinions from other people present. The questionnaire survey was conducted from February to December 2015 by myself and I recorded all responses directly onto the questionnaire sheet. A predator manual or field guide was used to ensure that participants identified predator species correctly.

Participation in the survey was voluntary and participants were advised to remain anonymous if they were uncomfortable disclosing their names (Romanach *et al*. 2007). Participants signed a consent form which was read to them by myself to facilitate sound understanding of its contents prior to signing. Compliance was met by obtaining Ethics Clearance and Research Permits from UNISA and the Botswana Government respectively. Participants were given an option to state 'no response' to any questions that they deemed to be of discomfort (White *et al*, 2005).

Questions not relevant to the individual being interviewed were captured as ‘not applicable’. Each questionnaire was completed in 15 to 20 minutes. Participants were categorized according to the cattle posts and/or farms based on their traditional names as given by their pioneer occupants at the time of their initial settlement or otherwise.

Physical inspection of kraals was conducted to determine the status of the kraals. Each kraal was rated according to their state of appearance as poor, average or good. The kraal structure was rated poor if the boundary was found to be weak and in a state that could allow easy penetration by both livestock and predators. A kraal structure was rated good based on a strong and intact boundary fence that would not allow for easy penetration of either livestock or predator. A kraal whose structure was neither too weak nor strong enough was rated as average.

5.2.2 Data Analysis

Responses from the open-ended questions were grouped or summarised according to their similarities using descriptive and qualitative approaches. The package SPSS was used to analyse questionnaire data. Geographic information system software (Quantum GIS 1.7.0) was used to map the distribution of the respondents within the study area. A Chi-square test of independence was used to find out if there were significant differences in livestock depredations incidences between the different cattle posts and if there were significant differences in livestock type predated on.

5.3 Results

A total of 92 respondents were interviewed across the six cattle posts surveyed (Table 5.1). Of these, 92% (n=85) were males and 8% (n=7) were females.

Table 5.1 Number of respondents interviewed per cattle post, n=92

Cattle Post	Bodumatau	Dinonyane	Dithobane	Kome	Machana	Ranches
No. of households	21	12	18	15	14	12

Twenty eight percent (n=26) were livestock owners while 72% (n=66) were employed fulltime herders, with ages ranging from 21 to 78 years. Generally, cattle posts had one person staying in each household but some (n=3) had four people, others (n=7) three people and some (n=18) had two people. Most (74%; n=68) of the respondents had been in the area for a period not exceeding five years while the other 26% (n=24) had been living in the area for more than five years. Most of the respondents (37%; n=34) had completed junior secondary education, 28% (n=26) primary education, 20% (n=18) senior secondary education and 2% (n=2) tertiary education. Twelve (13%) respondents had no formal education. The majority of participants (59%; n=54) viewed predation as the most challenging factor to farming practices in the area whereas drought and theft were indicated as the second most important challenge by (27%; n=25) and (30%; n=28) respectively. Diseases and an unreliable market were indicated as other challenges faced by the farmers in the area.

5.3.1 Evaluation of human-predator conflict in farmlands

The results of my study found that human-predator conflict was common across the surveyed farming area. Of the respondents interviewed 87% (n=80) claimed that they were losing livestock to predators whereas 13% (n=12) indicated that they were not. A Chi-square test of independence indicated a significant difference between respondents who indicated livestock loss to predation and those who did not, $X^2 = 14.287$, $p = 0.014$. Furthermore, the Chi square test revealed a significant difference on the perceived rate of livestock predation between cattle posts ($X^2 = 14.29$, $p = 0.014$). All respondents at the Dithobane cattle post (n=18) and the commercial cattle ranches (n= 12) generally lost livestock to predators (Figure 5.2), whereas 93% of respondents at both Kome (n= 14) and Machana (n=13) cattle posts claimed to lose livestock due to predation. Dinonyane and Bodumatau had 71% (n=8) and 61% (n=15) of the respondents claiming loss of livestock to predators respectively.

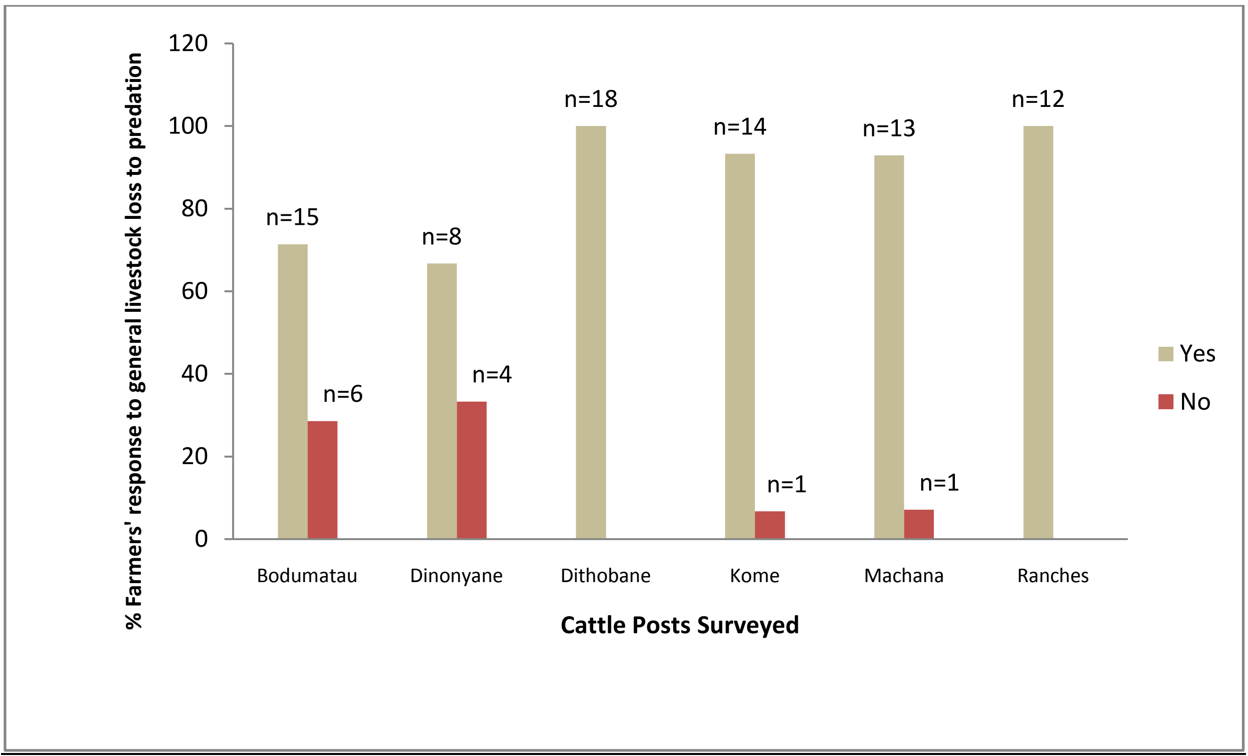

Figure 5.2 Farmers' responses on general livestock loss to predation expressed as a percentage of the number of farmers who lost or never lost livestock to predation

Jackal were generally regarded as the most problematic predator contributing to 92% (n=85) of livestock depredation incidents reported in the study area. However, leopards were perceived as the most problematic predator on the commercial cattle ranches where they accounted for 63% (n=7) of livestock depredation incidents. In addition, results suggest that farmers perceived caracal and brown hyena as the second most problematic predators with 23% (n= 21) of respondents indicating caracal while 21% (n=19) indicated brown hyena. However, these perceptions varied among the different cattle posts as caracal was regarded as the second most problematic predator by 44% (n=8) of the respondents at Dithobane and 67% (n =10) at Kome cattle post while brown hyena was indicted as the second most problematic species by 47% (n=7) of the famers interviewed at Machana and by 24% (n=5) at Bodumatau cattle post.

Further to livestock predation status, 71% (n= 57) of the respondents who experienced livestock loss to predators had some of their livestock attacked within 12 months before the interview. However, the Chi square test suggested no significant difference in perceived incidents of livestock losses between the different cattle posts in the 12 months before the interviews took place ($X^2 = 7.67$, $p = 0.176$). The majority (21%; n=12) of livestock attacks in the 12 months before the interview were reported from the Bodumatau cattle post followed by commercial cattle ranches (19%; n=11) (Figure 5.3). Dithobane and Machana cattle posts each had 18% (n=10), and Dinonyane cattle post had the smallest percentage (9%; n=5) of respondents who indicated livestock loss in the 12 months preceding the interviews.

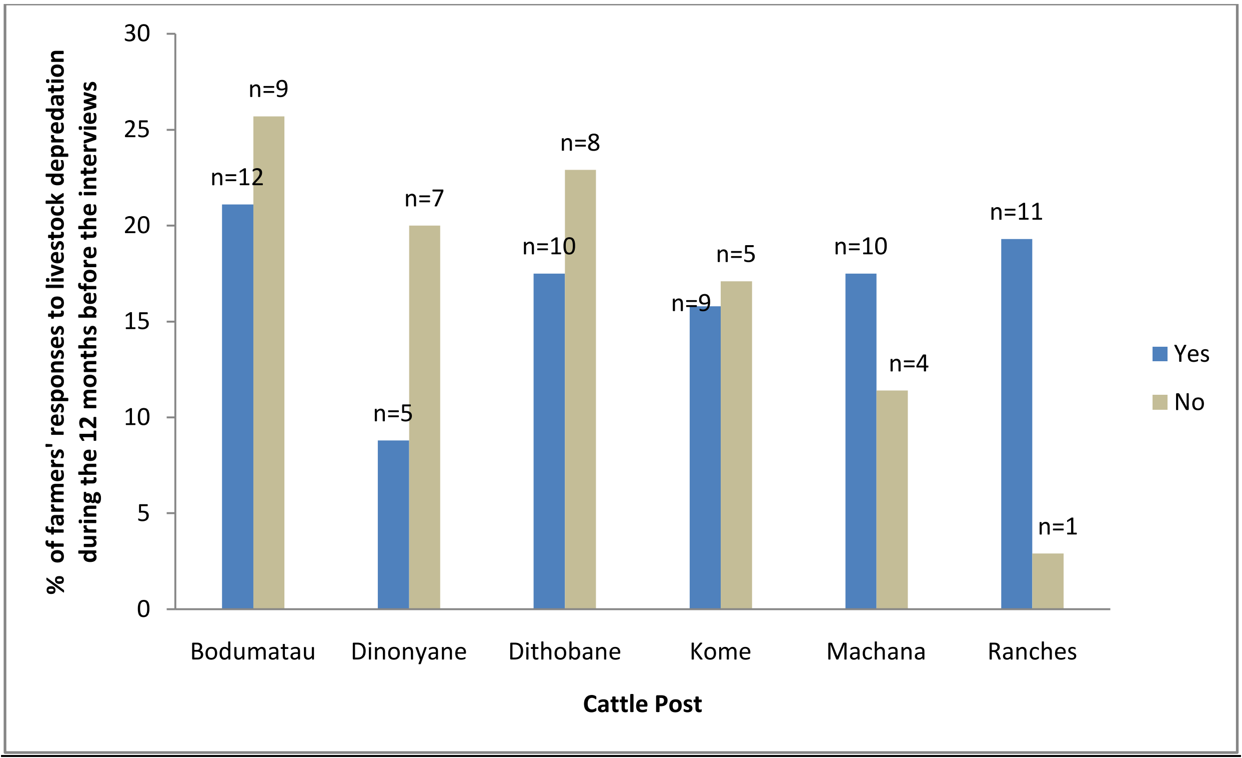

Figure 5.3 Farmers' responses to livestock predation in the 12 months before the interviews expressed as a percentage of the number of livestock lost in each cattle post

On the other hand, 39% (n=23) of the respondents who experienced loss of livestock to predators had not had any livestock attacked within the 12 months prior to the interview. The highest number of respondents who had lost livestock to predation but had no attacks in the 12 months before the interview were recorded at Bodumatau cattle post (n=9; 26%), and on the commercial cattle ranches (n=1; 3%) (Figure 5.3).

Respondents associated various predator species with the loss of their livestock. Results from the interviews indicate that 48% (n=44) of the respondents across the study area claimed to have lost livestock to jackal and 7% (n=8) to leopard. Caracal and brown hyena accounted for 3% (n=3) and 2% (n=2) respectively. Jackal predation accounted for 28% (n=12) of livestock predations at the Bodumatau cattle post, 21% (n=9) at Machana and 19% (n=8) at Dithobane (Figure 5.4).

However, jackal predations were lower (7%; n=3) on the commercial cattle ranches where leopard predations were perceived to be higher (86%; n=6). There were single (n=1) reports for cheetah and wild dog predation incidents at the Dithobane cattle post and commercial cattle ranches respectively (Figure 5.4).

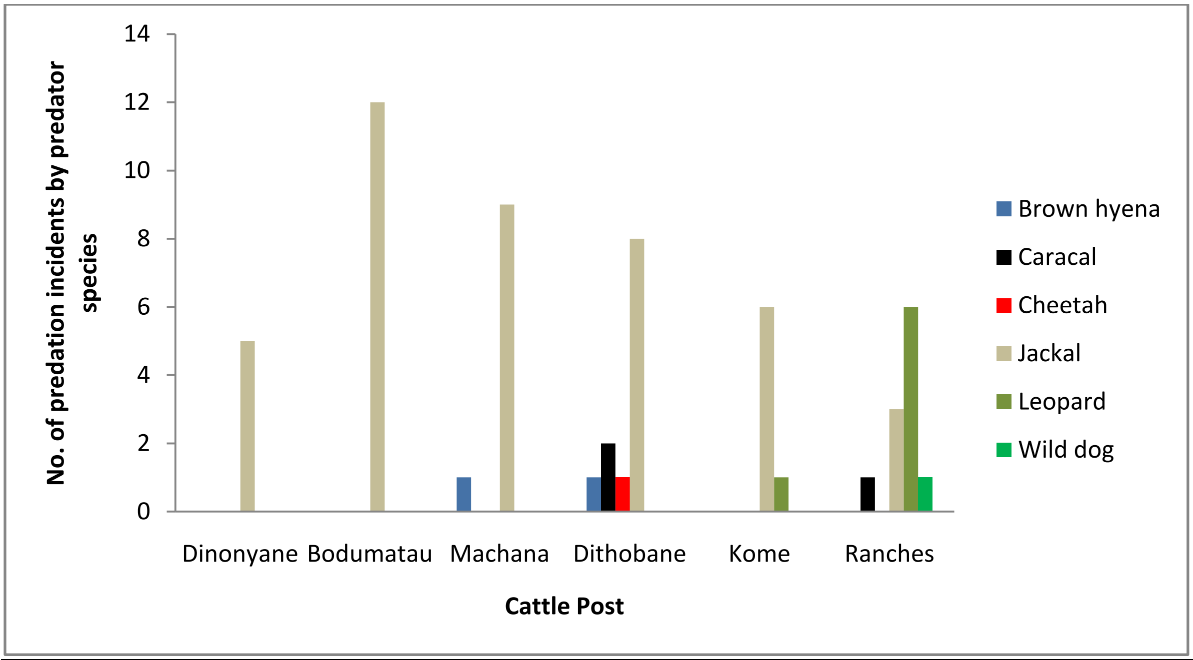

Figure 5.4 The number of predation incidents by predator species on cattle posts and cattle ranches

Small stock, particularly goats were affected most by predation. Goats constituted 70% (n=40) of perceived livestock loss to predation followed by sheep with 16% (n=9) and cattle with 14% (n=8) (Figure 5.5). The majority (28%; n=11) of respondents who lost goats in the 12 months preceding the interviews were from the Bodumatau cattle post followed by Machana (23%; n=9) and Dithobane (18%; n=8) (Figure 5.5). Although commercial ranches had the lowest incidences (8%; n=3) of goat predation they had the largest proportion (88%; n=7) of cattle lost to predation in the 12 months before the interview (Figure 5.5).

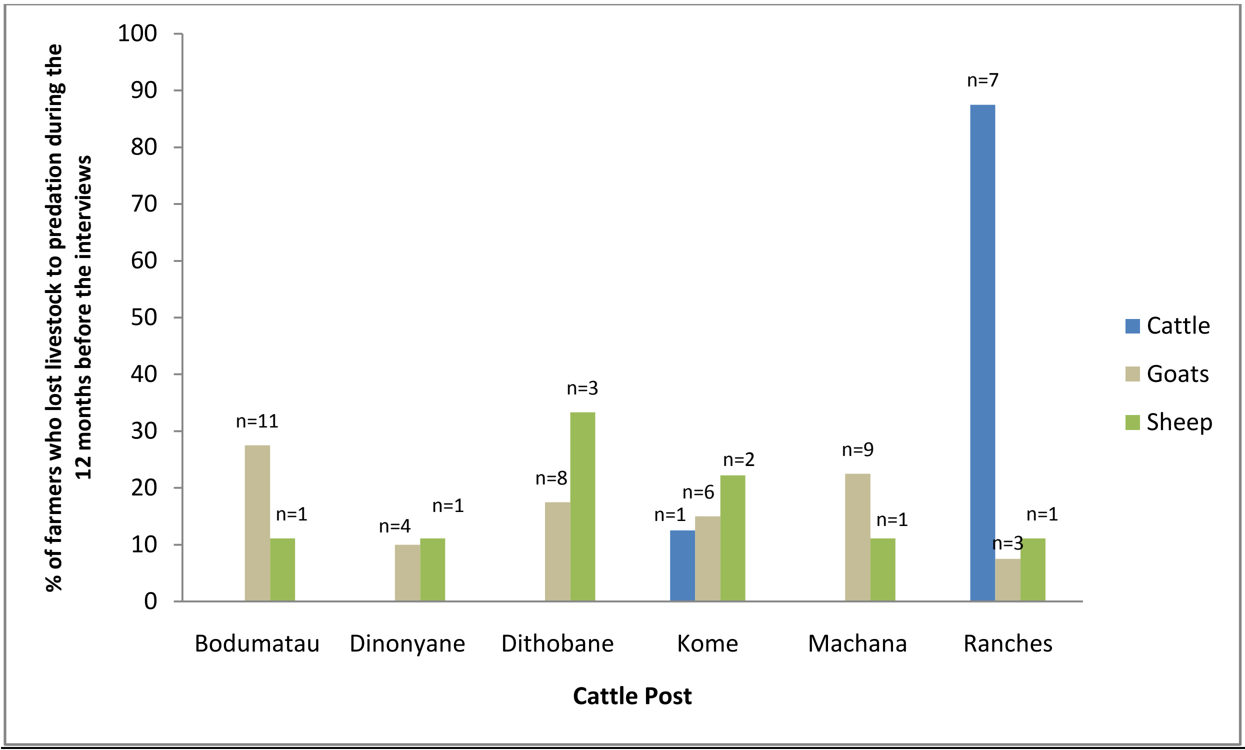

Figure 5.5: Percentage of farmers' responses on livestock lost to predation during the 12 months before the interviews

Although 38% (n=35) of the respondents did not lose livestock to predators during the 12months before the interviews, my study found that 95% (n=54) of the identified livestock predation took place outside of kraals while only 5% (n=4) occurred inside kraals. In addition, the majority (86%; n=49) of livestock losses took place during the day whilst only 14% (n=8) occurred at night. Furthermore, 50% (n=46) of the farmers interviewed related livestock attacks to seasonality whilst 33% (n=30) perceived attacks as unseasonal. The remaining 17% (n=16) did not know whether attacks were seasonal or not. The respondents who attributed attacks to seasons had different views with regards to the specific seasons of high livestock attacks. Of the 46 respondents, 59% (n=27) indicated that most of the attacks occurred in summer (August-April) while 41% (n=19) claimed attacks were predominantly in winter (May-July).

5.3.2 Conflict mitigation methods used

In the area of my study there were traditional mitigation methods used by farmers to protect their livestock from predators. Throughout the study area 72% (n=66) of the interviewed farmers owned cattle and of these, 63 (95%) of them used fencing to build their kraals whilst three (5%) used tree branches. In addition to cattle, 95% (n=87) of the interviewed farmers owned small stock and 95% (n=83) of them used fencing to make kraals whilst 5% (n=4) used branches. All small stock kraals were within 50m from homesteads whereas 98% (n=65) of cattle kraals were within 50m of homesteads and the remaining 2% (n=1) of the cattle kraals were located within a distance of more than 50m but not more than 100m from the homestead. The majority of the kraals for both cattle (62%; n=41) and small stock (63%; n=55) were in good condition. Only two (3%) cattle kraals and two (2%) small stock kraals were in poor condition (Table 5.2).

Table 5.2 Assessment of cattle and small stock kraal conditions

	Kraal status		
Kraal	**Good**	**Average**	**Poor**
Cattle	41 (62%)	23 (35%)	2 (3%)
Small stock	55 (63%)	30 (35%)	2 (2%)

The majority of the farmers did not like to kraal cattle at night with 83% (n=55) of the respondents not kraaling their cattle altogether at night. Only a few (12%; n=8) of the farmers interviewed kraaled their cattle at night. Other farmers (5%; n=3) preferred to kraal cattle at night only during the ploughing season in order to keep livestock away from other people's crop fields. In contrast, all small stock farmers kept their stock kraaled at night. My study also found that farmers preferred to separate young livestock (both cattle and small stock) from adults when livestock was released to graze during the breeding season and kept young individuals in the kraals.

Herding was not a common practice in the study area as 60% (n=55) of the respondents did not herd their livestock at all during the day. Only 40% (n=37) of farmers herded their livestock but only during the ploughing season. From the interviews, it was found that 87% (n=80) of the farmers did not use livestock guarding dogs as a conflict mitigation method. Livestock record keeping was also rarely practiced in most of the cattle posts surveyed, with only 20% (n=18) of the respondents confirming that they did keep records such as those at: Dinonyane with 33% (n=4) and Bodumatau cattle post with 14% (n=3) (Figure 5.6).The majority of the farmers (57%; n=10) who did keep records were those farming on the commercial cattle ranches (Figure 5.6).

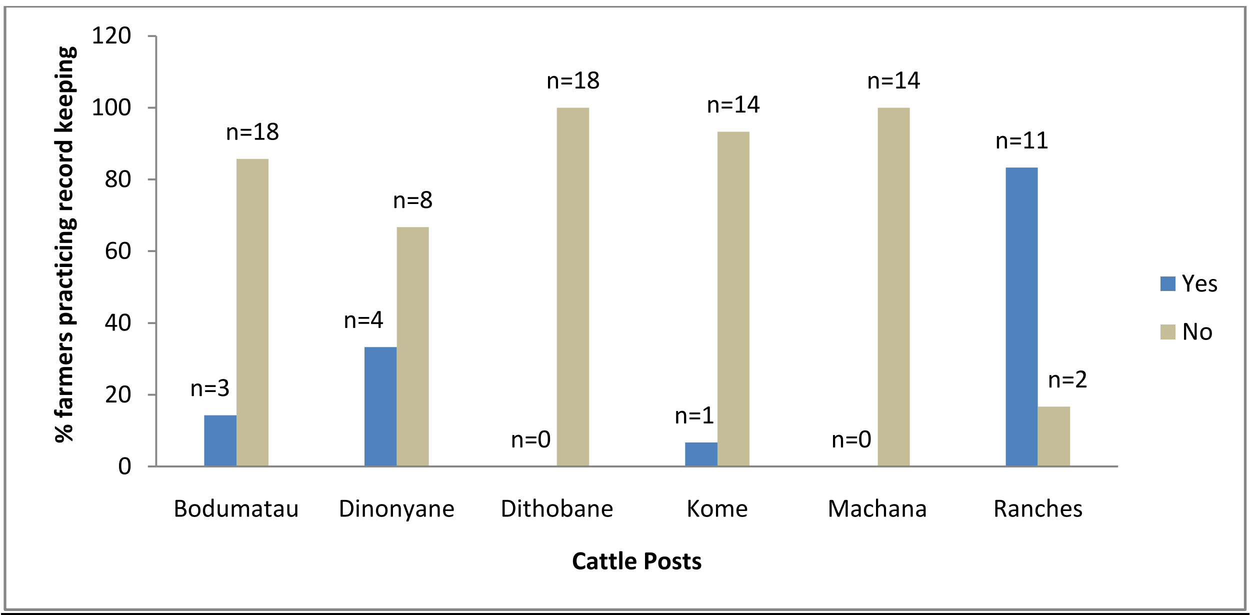

Figure 5.6 Comparison of farmers' responses on the use of record keeping at the cattle posts

5.3.3 Farmers' perceptions on the conflict status relative to the existence of JGP

Most of the farmers in the study area believed that the majority of the predator species that occupied their farmlands were not residents to the area but were coming from other places. Of the 92 respondents interviewed, 55 (60%) were of the view that predators came from JGP whereas 16 (17%) of them believed that they came from JGP as well as from the commercial cattle ranches. Only 23% (n=21) of the respondents were not sure whether predators were residents of the farmlands or if they originated from elsewhere. Brown hyena was singled out by 38% (n=35) of the respondents as the only predator that was not resident to the farmlands while 21% (n=19) indicated caracal and brown hyena. Five percent of respondents (n=5) singled out leopard and brown hyena whereas 23% (n=21) believed that all the predators found on their farmlands were not residents but rather came from somewhere else. Thirteen percent (n=12) could not state if predators resided in their farmlands or if they came from other places. Twenty nine percent (n=6) of the respondents who perceived all predators as non-residents of their farmlands were from the Bodumatau cattle post, 24% (n=6) from Dithobane cattle post and 19% (n=4) from Kome cattle post and commercial cattle ranches. Bodumatau and Machana cattle posts had the highest number (n=12; 34% each) of respondents who believed that brown hyena was the only predator that visited their area from elsewhere. Some farmers were of the perception that caracal and brown hyena were the only predators that were not residents of their farmlands with 68% (n=13) of them being based at Dithobane while 32% (n=6) were based at Kome cattle post. All respondents who implicated leopard and brown hyena as visitors from JGP were farming on commercial cattle ranches.

Twenty three percent (n=21) of respondents were of the perception that cattle posts had too many people which disrupt wildlife occupancy thus forcing predators to occupy areas with minimum human habitation such as JGP and commercial cattle ranches. Thirteen percent (n=12) of the respondents could not justify the reasons why they thought predators were not residents on their farmlands. Most (57%; n=52) of the farmers who associated predators with JGP stated that predator tracks which they encountered on their lands often move in the direction of JGP.

5.3.4 Farmers' reactions to livestock predation and suggestions for solutions

The farmers reacted in various ways to loss of their livestock to predators. Of the 87 farmers that complained of livestock depredation, 59% (n=51) reported losses to livestock owners and they did not know what actions were taken thereafter. Eighteen percent (n=16) reported the losses to the Department of Wildlife and National Parks (DWNP) while 6% (n=5) used domestic dogs to hunt and kill the alleged predator. Another 2% (n=2) used firearms to hunt and shoot the predators thought to be responsible for the livestock predation.

Farmers however had some suggestions towards the resolution of the human-predator conflict issue in the area. Thirty eight percent (n=35) of the farmers suggested that government should include jackal in the list of species that attract compensation, whereas 30% (n=28) suggested a decrease of predator numbers. Seventeen percent (n=16) wanted predators to be removed from their farmlands and be translocated to protected areas.

5.4 Discussion

The level of human-predator conflict in the farmlands surrounding JGP poses an economic threat to livestock owners as does this kind of conflict elsewhere in Botswana (Hemson 2003; Schiess-Meier *et al*. 2007; Gusset *et al*. 2009; Hemson *et al*. 2009) and many other parts of the world (Welch *et al*. 2016). The results of my study indicate that most of the farmers interviewed reported loss of livestock to predators. Furthermore, 62% of the farmers who reported livestock loss had incidences of livestock predation within the 12 months before the interviews resulting in 184 livestock lost. Livestock remains the primary source of income and livelihood for many of the African rural communities (Behnke 2010). Over and above this, livestock is one of the economic pillars that contribute significantly towards the Growth Domestic Product (GDP) in many African nations (Metaferia *et al*. 2011). Losing any livestock regardless of the scale at which it happens affects the prosperity of livestock production and translates into direct livelihood and economic loss to livestock owners (Gusset *et al*. 2009).

Although not as extreme as in areas with high species richness of obligate predators such as Northern Botswana (Gusset *et al*. 2009; Hemson *et al*. 2009). The results indicate that JGP had a significant number of predator species that include big cats such as leopards. This suggests that conservation authorities need to engage with local communities to enhance their participation in predator friendly livestock management thereby instilling positive attitudes towards predators (Sillero-Zubiri & Laurenson, 2001). The majority of the livestock losses in the study area were perceived to be due to jackal predation. For many decades, jackal has been viewed as vermin in many farming areas across Southern Africa (Bothma 1971a; Rowe-Rowe 1976; Roberts 1986; Humphries *et al*. 2015). For example, jackal constituted 72% of reported livestock losses in the Kwazulu Natal province of South Africa (Humphries *et al*. 2015) whereas another study in Kwazulu Natal found that 68% of sheep losses resulted from jackal predation (Lawson 1989). These results conquer with the results of my study where 92% of livestock predations were perceived to be of jackal.

In addition to jackal, caracal and brown hyena were also implicated among the problem causing animals in the study area even though the significance of their attacks varied among the cattle posts. The majority of caracal attacks were reported on the cattle posts which are relatively closer to the park boundary such as Dithobane and Kome, whereas brown hyena was implicated across the entire study area. Although they are predominantly scavengers (Welch *et al*. 2016), brown hyenas are still perceived to be dangerous to farmers (Hofer & Mills 1998) because they sometimes attack and kill livestock causing considerable damage (Schiess-Meier *et al*. 2007). In their analysis of Problem Animal Control (PAC) data for the Kweneng district in Botswana, Schiess-Meier *et al*. (2007) found that brown hyena accounted for 11.8% (n=269) of livestock attacks reported between 2000 and 2002. The results of my study are in line with the findings from other studies elsewhere (Rowe-Rowe 1976; Roberts 1986; Lawson 1989; Humphries *et al*. 2015). However, it should be noted that losing livestock to predators contributes to perceptions that can influence exaggerations with regards to depredation reports and the overall status of the conflict (Anthony *et al*. 2010). Various factors can lead to exaggeration of livestock predation reports. For example, when livestock is not correctly monitored, livestock losses may not be attributed to causes other than predation (Humphries *et al*. 2015) or when farmers already have unwarranted negative attitudes towards predators (Kellert 1985; Mizutani 1995; Rasmussen 1999). In addition, exaggeration of livestock depredation can occur when individuals anticipate possible benefits that are likely to come from either compensation schemes or by increasing the farmers' chances of being targets of outreach activities (Holmern *et al*. 2007). Another factor that is likely to affect the accuracy of conflict reports is the misidentification of the predator species responsible for loss of livestock (Ott *et al*. 2007). Whilst livestock predation can, and in some areas does contribute to livestock losses, other causes of livestock mortalities need to be considered and quantified. In the Kweneng District of Botswana, 251 stock heads from different guilds were lost to predators when compared to a combined total of 390 livestock heads that were lost to other causes such as diseases, motor vehicle accidents and starvation (Schiess-Meier *et al*. 2007). In the Pantanal region of Brazil, the majority of livestock mortality resulted from drowning, disease and starvation, and not from jaguar predation as was originally alleged (Schaller 1983). Roberts (1986) also found that domestic dogs were responsible for 83% of the 395 sheep attacks that were originally associated with jackal in Kwazulu Natal. These findings therefore suggest that predation is not always responsible for loss of livestock and as such a careful assessment of the causes of livestock mortality is required in affected communities.

The implication of jackal and caracal being the most problematic predators in the study area is not surprising. With the loss of habitat across most of the African savannas (Ritchie & Johnson 2009),smaller predators such as caracal and jackal are assuming the role of top predators within pastoral lands due to elimination of large apex predators such as lion (Humphries *et al*. 2015). Concurrent to my results, caracal was reported as the second most problematic predator after jackal in a different study at Kwazulu Natal, South Africa where it was responsible for 14% of reported livestock losses (Humphries *et al*. 2015).

The extent of livestock depredation can further be related to the availability and vulnerability of other prey species (van der Merwe *et al*. 2009). The increase in pastoral farming results in competition between domestic and wild herbivores. When out-competed or hunted, wild herbivore numbers decrease ultimately forcing predators to adapt and feed on abundant and easy to catch livestock in response to the scarcity of natural prey (Sillero-Zubiri & Laurenson 2001; Kaunda & Skinner 2003). Within the areas around JGP there has been a considerable increase in human habitation as a result of government programs that aim to address youth unemployment by funding them to venture into farming. This increase in human habitation and livestock farming will inevitably affect the densities of natural prey base leaving small stock as the most abundant prey and subjecting them to vulnerability (Blaum *et al*. 2009). The findings of my study where jackal is regarded as the most problematic predator and small stock as the most affected guild is unsurprising due to the possible reduction of natural prey partnered with high jackal density as a result of increased human habitation (Graham *et al*. 2005). This notion is further supported by the fact that jackal is adapted to hunt small-medium prey with body mass ranging from 14-30kg (Hayward *et al*. 2017) which is facilitated by the presence of high densities of small stock. Owing to their smaller size, increased small stock predation in some parts of the world (such as in Montana, Utah, New Mexico, Arizona and Wyoming) has led to abandonment of goats and sheep operations with farmers shifting to larger livestock that are less prone to coyote (*Canis latrans*) predation (Bowns 1982).

On the commercial cattle ranches in my study leopards were perceived as the most problematic predator species by livestock owners. A similar observation was made by Chase Grey *et al*. (2017) in the Soutpansburg mountains area (South Africa), where livestock owners ascribed most of their cattle losses to leopard predation. Cattle were the most abundant livestock guild on the commercial cattle ranches and because of their large body mass (>120kg) jackals could not predate on them (Hayward *et al*. 2017). Predation of cattle calves by leopards is not surprising because their body enables them to kill prey of body mass ranging between 5-70kg (Norton *et al*. 1986; Bailey 1993). Lower jackal predation incidents on the commercial cattle ranches could therefore possibly be associated to the presence of apex predators such as leopards coupled with decreased preferred prey biomass of small stock that was not kept in most of the camps inside the cattle ranches.

A number of traditional conflict mitigation techniques were known by the interviewed farmers who live on the land adjacent to JGP but despite this, techniques were not efficiently implemented. Traditional mitigation methods evaluated in my study included herding, kraaling at night, use of livestock guarding dogs and livestock record keeping. While the study ascertained that all the livestock owners interviewed had some structures designed to enclose livestock during periods of high vulnerability, the use of these structures varied between the different livestock guilds. All farmers who owned small stock kraaled them at night while a small fraction of the cattle owners kraaled cattle, but only during ploughing season to prevent livestock from destroying people's crops at night. These results are consistent with other studies in suggesting that management of small stock is often more intense compared to that of cattle. For example, only 27% of the farmers kraaled cattle at night in the Kalahari region of Botswana whereas 68% kraaled small stock (Klein 2013). This practice has been related to the smaller size of small stock which makes them more vulnerable to predator attacks than larger stock (Klein 2013). Similarly, lack of cattle kraaling can be associated with the absence of larger predators such as lions in the area.

Reports of jackal as the most problematic predator species in this study (accounting for 92% of reported livestock attacks) are supported by other studies that found large proportions of small stock remains in the diet of jackal (Bothma 1971b; Stoddart *et al*. 2001; Humphries *et al*. 2016). However, there have also been occasional cases where jackals have attacked and killed sick cattle and newly born calves (Skead 1979). The findings of my study indicate that livestock owners understand the importance of kraaling small stock at night as they are comparatively prone to predation as opposed to large livestock such as cattle.

Over and above protection of livestock from predators, kraaling plays a crucial role in preventing theft of livestock (Ogada *et al*. 2003) and also giving farmers an opportunity to identify sick and missing animals (Schiess-Meier *et al*. 2007). Because of their relatively small body size, small stock is more susceptible to theft than cattle (Bowns 1982) and kraaling them close to homesteads at night reduces theft. The presence of humans closer to the kraals keeps the livestock care takers in a better position to hear and react timely to any form of attacks (predator and human) that takes place on kraaled livestock. Moreover, predators tend to avoid kraals that are located in the proximity of human habitation (Frank 2010). This phenomenon supports the findings of my study which revealed that livestock attacks occurred predominantly outside the kraals because almost all the kraals of the participants were located within a distance of 50m from homesteads. Farmers in this study used similar kraaling materials (mainly fencing and branches) to construct the kraals for their livestock. The poles were either bought from local timber suppliers in form of treated gum poles or derived from local tree species such as *Dichrostachys cinerea*. The majority of kraals were properly constructed and still in a good condition thus ensuring livestock was protected efficiently. In addition, both small stock and cattle farmers were consistent in maintaining a short distance between kraals and the homesteads. When kraals are located closer to human habitation predators become reluctant to approach the kraals as was observed at Kenya's Laikipia District against lions (Frank 1998). Locating kraals closer to homes becomes even more effective when dogs are present at the homesteads as they often alert people allowing them to act before predators can start attacking livestock (Frank 1998).

Active livestock herding has been found to provide a substantial diminution on livestock loss (Kruuk 1980; Ogada *et al*. 2003; Woodroffe *et al.* 2007). In spite of reported successes, herding was not a common practice among livestock owners in the study area with only 40% of interviewed farmers herding livestock and only during the ploughing season to prevent stock from damaging other people's crop. The benefits of herding to mitigate human-predator conflict are immediate because the method allows for avoidance of predator hot spots as well as quick and flexible responses to predator attacks. Furthermore, herding also allows for timely recognition of ill livestock that may be easy victims of predation (Woodroffe *et al.* 2005). Active livestock herding is not currently practiced the way it was done in the past (Kgathi *et al*. 2012). This reduction in livestock herding is associated with a change that has happened over time in general livestock husbandry, partnered with a decrease in the number of people employed on cattle posts (Rasmussen 1999). In Shorobe, northern Botswana, only 17% of the farmers practiced active herding even though the area was a host to larger predators such as lions, leopards and spotted hyenas (Kgathi *et al*. 2012). A number of factors have been associated with the lack of active livestock herding. For example, herders at the Mbirikani ranches of Kenya did not accompany livestock when they were busy talking, sleeping or collecting the Mira plant (*Catha edulis*) (Mwebi 2007). New livelihood activities as well as reduced number of non-school going family labour has also been implicated as possible factors that contribute to the decline of active herding (Kgathi *et al*. 2012; Weise *et al*. 2018).

In my study, it was further noticed that most of the farmers did not have livestock guarding dogs with their livestock herds despite the fact that they were all aware of the method during the interviews. Reasons for the low uptake of using livestock guarding dogs by the farmers in my study are not clear because the technique has been found to be comparatively cheap particularly when the local breeds are used (Horgan 2015). However, the cost effectiveness of livestock guarding dog as a technique can be compromised by the intensity of the conflict in one particular area (Green *et al.* 1984). If well integrated and implemented, proper livestock husbandry techniques can play a magnificent role in declining livestock depredation incidents on pastoral lands (Ogada *et al*. 2003; Woodroffe *et al.* 2007).

A holistic approach is crucial for the successful fight against predator-livestock conflict. This entails a systematic combination of simple but effective conflict mitigation techniques that can efficiently reduce livestock predation at the individual farmer level (Anthony & Wasambo 2009). Record keeping is a simple method that assists farmers track and monitor areas where predators are a threat and to help farmers recognise weaknesses and strengths in their livestock husbandry practices. Record keeping can also inform livestock owners about the seasons of high livestock predation as well as the predator species that are frequently involved. Having the information ready will help the farmers to make informed long term decisions and prioritize on how best they can deal with predators and other farm operation problems as communicated by the farm records. Record keeping was not very well employed by the farmers in this study; this could be because farming in the area is generally at a very low scale using traditional livestock management styles. Insufficient livestock recording has also been observed in the western Serengeti in Tanzania (Nyahongo & Roskaft 2012). A study conducted among small scale farmers at the Cross River State in Nigeria found that only 32% (n=251) of the farmers interviewed kept records while the other 68% (n=534) did not keep any records (Dudafa 2013). This lack of record keeping was related to the farmer’s literacy level because 65% of the respondents were placed in a category of illiterate farmers (Dudafa 2013). At Bukedi Subzone of Uganda, a lack of awareness and limited capacity were outlined as the key reasons for failure to keep livestock records (Gidoi *et al*. 2015). The results in some way support the findings of my study where record keeping was found to be practiced more on the commercial cattle ranches than on communal cattle posts where farming is practiced at a subsistence level. Although level of literacy was high in my study area record keeping was poor suggesting that there is possibly little value seen in this method.

The interaction of livestock and wildlife near protected areas is a common phenomenon in Africa (du Toit 2011). These interactions result in wildlife competing with livestock for resources and sometimes livestock being attacked and killed by wild predators (Tessema *et al*. 2010). As in other parts of Africa where farmers blamed protected areas for livestock loss through predation (Anthony 2007; Yosef 2015), farmers in my study also associated livestock depredation in their farmlands with JGP.

Unlike the studies conducted in Ethiopia that found over 70% of positive local community attitudes towards wildlife (Tessema *et al*. 2010; Yosef 2015; Biru *et al*. 2017), the results of my study found that most respondents (84%) had a negative attitude in local communities towards predators indicating that there is no other benefit from wild animals other than losing livestock. Only 17% (n=16) of the respondents indicated tourism activities as a possible benefit that could be derived from the presence of predators in their farming areas. Furthermore, the majority (75%) of the farmers in my study perceived predators as coming directly from JGP to predate on their livestock before heading back.

Differences in attitudes could be attributed to a number of factors including household economic benefits derived by communities from wildlife related activities (Biru *et al*. 2017), communities' socio-cultural relationship with protected areas (Tessema *et al*. 2010) as well as the distance of the cattle post from the park (MacKenzie & Ahabyona 2012; Yosef 2015; Biru *et al*. 2017). In the context of my study, farmers had similar perceptions towards JGP with regards to its contribution into the livestock depredation incidents. This could be due to the fact that the proximity of all the surveyed cattle posts was similar with regards to their location and distance from the boundary of the JGP.

However, it is worth noting that of the predator species that were implicated as problem causing animals only brown hyena, caracal and leopard were perceived to be coming from JGP, while jackals were believed to be full time residents of the respective farm lands. These findings therefore do not fully support the farmers' allegations that JGP is the source of predators that attack and kill their livestock.

5.5 Conclusion

Farmers living in the vicinity of JGP are not an exception to human-predator conflict experienced by communities who live closer to protected areas elsewhere in the world. The extent of livestock depredation in the area is considerable. However, farmers' perceptions on the most problematic predator species differed, with jackal and leopard being the most problematic predator on communal cattle posts and commercial cattle ranches respectively. Predation of small stock was more prevalent than that of large stock such as cattle which resulted in some negative attitudes of the farmers as they believe that JGP is the sources of predators that feed on their livestock. However, despite this, jackal being perceived as the most problematic predator was believed by the farmers to be natural inhabitants of the farmlands and not originating from JGP. These findings imply that the extent of human-predator conflict in the area is not entirely dependent of the presence of JGP, but the park is likely to contribute to some degree as resident predators are able to access the area on the edge of the park.

Results from my study further demonstrate inefficiency on the implementation of traditional conflict mitigation methods, a potential factor that influenced the escalation of livestock depredation incidences. If properly implemented, traditional predator control techniques can effectively reduce predator livestock attack occurrences (Woodroffe *et al*. 2007). Efficient implementation of conflict mitigation strategies is necessary to tackle the conflict and enhance positive attitudes of the farmers in respect of predator and general wildlife conservation. Conservation education should also be made a priority by JGP Management and other relevant stakeholders in the area to sensitize communities about the probability of co-existence as a tool that would benefit both farming and conservation efforts by promoting tolerance and enhancing behavioural change among the affected communities in the proximity of the game park.

Chapter 6

General Conclusions and Recommendations

6.1 General Conclusions

The aim of the study was to investigate the occupancy of predators of Jwana Game Park and their potential contribution to livestock depredation on neighbouring farmlands. The study found that at least seven medium-large predator species occur in the game park. Occupancy estimates for predators varied across the park with brown hyena and jackal having the highest occupancy estimate. These results are encouraging because they provide valuable information on the conservation status of JGP' predator population which could not be provided by the park's current game population monitoring programme.

Jwana Game Park's boundary fence had holes of various sizes underneath that enabled movement of predators between the game park and the adjacent farmlands. However, there was no apparent relationship between predator movement in different sections of the park and the holes with signs of intensive animal movement.

My study further found that the majority of livestock farmers on the farmlands surrounding JGP reported livestock loss to predation, and that jackal was perceived to be the most problematic predator in most parts of the study, except for the commercial cattle ranches. Livestock loss could be influenced by inefficient implementation of simple but effective traditional conflict mitigation methods. The intensity of conflict mitigation methods was found to be applied more to small stock than cattle, which can be attributed to the body size of small stock that rendered them more vulnerable to predation than cattle. Improved livestock husbandry practices are required in order to reduce the current human-predator conflict in the area, especially since farmers perceive jackal to be resident in the farmlands and not to originate from JGP.

In conclusion, the extent of farmer-predator conflict in the farmlands surrounding JGP was influenced by two main factors (1) the ability of predators to move in and out of JGP and (2) the inefficient implementation of traditional conflict mitigation methods that exposed livestock particularly small stock to predation.

6.2 Implications for predator conservation

The slow recruitment of predators and their specialized habitat requirements increase their dependency on protected areas, reducing their population viability and increasing their risks of extinction (Woodroffe & Ginsburg 1998). Being the only protected area in its geographical location; JGP remains a very important site for the conservation and protection of medium-large predators especially species with low density such as cheetah and wild dog. In spite of their relatively small size, the contribution of protected areas particularly in the metapopulation management of endangered species is considerable (Davies-Mostert *et al*. 2009). The JGP is comparatively small in size covering an area of only 190.85 km^2 which implies that predator species with larger home ranges are forced to make use of adjacent land to enlarge their home ranges in order to acquire resources. The ability of species to move in and out of protected areas remain an important conservation tool in preventing the possible species inbreeding depression associated with small populations. For example, the home range of brown hyena can be as large as 4, 370km^2 based on minimum convex polygon (MCP) methods and 2, 570km^2 based on kernel methods (Wiesel 2006), while that of leopard can range between 30 and 78km^2 for males and between 15 and 16km^2 for females (Bothma & Walker 1999). Cheetah home ranges can vary between 11km^2 (Purchase & du Toit 2000) and 833km^2 (Caro 1994) with sex, prey availability and cover tending to influence the overall size of their home ranges (Purchase & du Toit 2000). The home range for jackal is slightly smaller than that of caracal with the former ranging between 3.4km^2 and 21.5km^2 (Ferguson *et al*. 1983) and caracal home ranges estimated between 3.9km^2 and 48km^2 (Tawari 2009).

The study also demonstrates that occupancy modelling remains one of the tools for monitoring species in protected areas especially when species abundance estimation is difficult (MacKenzie & Nichols 2004). By analyzing camera trap data in the context of the occupancy framework, the study has generated occupancy estimates for medium-large predators of Jwana Game Park. This information can be used as baseline data for future monitoring of predator population trends within the park. Camera traps also remain a valuable tool for collecting and managing species inventories especially when species are rare, nocturnal, and elusive. Over the years, management of JGP has used aerial surveys to monitor game populations, which is not suitable for predator surveys. The use of camera traps specifically for monitoring of the predator species in JGP would provide managers with valuable information on current predator occupancy as well as long term population trends.

6.3 Future Recommendations

The success of predator population monitoring in protected areas is dependent on the correct choice of population monitoring techniques. Therefore, to ensure successful monitoring of predator population trends, JGP management should consider the use of the camera traps in addition to aerial counts which has not been very successful over the years in monitoring the park's predator population. Because camera trapping allows for frequent sampling, management will be able to monitor trends and changes that may take place in the parks' predator species population. This technique will further provide them with information of available digging animals and help them develop a required fence maintenance plan that is informed by the digging behavior of such species.

Proper livestock husbandry is crucial in optimization of livestock production benefits. Furthermore, traditional conflict mitigation methods have been effectively used in many parts of the world to control predation impacts on domestic stock. As such, farmers in the proximity of JGP have an opportunity to decrease the extent of human-predator conflict in their farmlands. An efficient integration of traditional conflict mitigation methods such as night kraaling, active herding and use of livestock guarding dogs would reduce the vulnerability of livestock to predators thus increasing farmers' tolerance on predators. Raising awareness in form of workshops and other means is required to inform farmers on the potential effectiveness of the available livestock management methods in reducing livestock depredation.

Although my study was able to establish the occurrence and general distribution of medium-large predators in JGP an opportunity for further research is to investigate factors such as inter-predator species interactions and prey availability that may influence the current predator occupancy and distribution in JGP. In addition, prolonged surveys and/or an increased number of camera traps in the study site are required to examine species with very low detection probabilities such as cheetah and wild dog. Future studies should also undertake a detailed investigation on the relationship of the medium-large predators that reside in JGP in order to understand how they influence the populations of one another. In addition, it is critical to investigate species-specific conservation needs for low density predators particularly cheetah that used to be relatively abundant in JGP in the past. It is also critical for future studies to have a closer look at the potential factors that could have influenced alternating occupancy estimates of leopard and brown hyena in different sections of the JGP.

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APPENDIX

UNISA university of south africa

CAES ANIMAL RESEARCH ETHICS REVIEW COMMITTEE

Date: 12/03/2015

Ref #: **2015/CAES/020**
Name of applicant: **Mr M Kokole**
Student #: **53317726**

Dear Mr Kokole,

Decision: Ethics Approval

Proposal: An investigation into the socio-ecological factors influencing human-carnivore conflict around Jwana Game Park, Botswana

Supervisor: Dr L Rutina

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Animal Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

Please note point 4 below for further action.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Animal Research Ethics Review Committee on 11 March 2015.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Animal Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable*

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REFERENCE: EWT 8/36/4 XXVII (12)

REPUBLIC OF BOTSWANA

MINISTRY OF ENVIRONMENT,
WILDLIFE AND TOURISM
PRIVATE BAG BO 199
GABORONE
BOTSWANA

ALL CORRESPONDENCE MUST BE ADDRESSED TO THE PERMANENT SECRETARY

9th July 2014

MORULAGANYI KOKOLE
P.O BOX 502121
GABORONE

Tel: 5881132/ +267 7294 119
Email: kokolemr@yahoo.com

APPLICATION FOR A RESEARCH PERMIT: "AN INVESTIGATION IN TO THE SOCIO-ECOLOGICAL FACTORS INFLUENCING HUMAN-CARNIVORE CONFLICT AROUND JWANA GAME PARK, BOTSWANA": EWT 8/36/4 XXVII (10)

We are pleased to inform you that you are granted permission to conduct a research entitled: **"An Investigation in to the Socio-Ecological Factors Influencing Human-Carnivore Conflict around Jwana Game Park, Botswana"**

The research will be conducted in **Jwana Game Park (Jwaneng) and farmlands within 20km from the Park.**

This permit is valid for a period effective from **1st September 2014 to 31st August 2015.**

This permit is granted subject to the following conditions:

1. Signing and submission of an Agreement between Government of Botswana and Independent Researchers.

2. Progress should be reported periodically to the **Department of Wildlife and National Parks.**

3. The permit does not give authority to enter premises, private establishments or protected areas. Permission for such entry should be negotiated with those concerned.

4. You conduct the study according to particulars furnished in the approved application taking into account the above conditions.

5. Failure to comply with any of the above conditions will result in the immediate cancellation of this permit.

6. The research team comprises of **Morulaganyi Kokole.**

1

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CONSENT FORM

TITLE OF RESEARCH PROJECT

An Investigation into the Socio-Ecological factors influencing Human-Carnivore conflict around Jwana Game Park, Botswana.

Dear Mr/Mrs/Miss/Ms_______________________________ Date ___________________________

NATURE AND PURPOSE OF THE STUDY

The purpose of this study is to investigate the human carnivore conflict status as well as factors that influence it. It seeks to collect information onconflict mitigation strategies used in the study area and individual farmers perceptions on the use of such methods as well as socio-economic status of the farmers. The study uses face to face interviews to gather this information and only livestock farmers who fall within the 20km radius from Jwana Game Park will be interviewed. Only people who have been in the area foe at least one year can be interviewed. Only people over the age of 18 years old can be interviewed.

RESEARCH PROCESS

The study requires your participation in the following manner:

- Answer the questions from the questionnaire. as read to you by the researcher or assistants
- The researcher or assistants will read the questions in the language you understand and complete the questionnaire form for you as you answer.
- There are no right or wrong answers, all of them will be valuable for this study.
- Feel free to give information to the best of your knowledge; it does not need to be pleasing to the interviewee.
- The interview should take approximately 15 minutes to complete.

If you have any questions about the study, please feel free to contact Mr MorulaganyiKokole (Researcher) at 72941197 or 73517453 or Dr Lucas Rutina (my research supervisor) at 717375225/75324134.

CONFIDENTIALITY

Your participation in this research project is completely voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation. You may also leave blank any questions you don't wish to answer. There are no known risks to participation beyond those encountered in everyday life. Your responses will be confidential and data from this research will be reported only as a collective combined total. No one other than research staff will know your individual answers to this questionnaire.

WITHDRAWAL CLAUSE

I understand that I may withdraw from the study at any time. I therefore participate voluntarily until such time as I request otherwise.

POTENTIAL BENEFITS OF THE STUDY

A number of farmers in your area perceive Jwana Game Park as a source of livestock depredation in their farmlands. This study will therefore help us to investigate these perceptions and also evaluate whether or not the conflict mitigation methods applied effectively reduce the livestock attacks. This information will also enable us to recommend best practices that can effectively reduce livestock loss to large carnivores.

INFORMATION (contact information of your supervisor)

If I have any questions concerning the study, I may contact Dr Lucas Rutina, at 6817235/71737225 or Dr Slater, at 00267 11 471 2342.

CONSENT

I, the undersigned, ________________________ (full name)have read the above information relating to the project and have also heard the verbal version, and declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the project with the project leader, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred as a result of the project/trial or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received a signed copy of this consent form.

Signature of participant: ....

Signed at ………………………………… on …………………………………

WITNESSES

1 ....

FARMER QUESTIONAIRE					
Date		**Interviewer**		**Q.No:**	
Coordinates	**S:**	**E:**			
Section A:	**Back Ground of the farmer**				
Name			Anonymous		
Are you:	owner	herder	worker	other	
How long have you been in the area?					
Age		Sex			
Name of the tribal lands/Cattle post:					
Section B:	**Socio-Economic Details**				
Educational Back Ground					
Non	Primary	Junior	Senior Secondary	Tertiary	
Employment					
	Full-time Farmer	Government	NGO	Self-employed	Other
Number of livestock					
Goats	Sheep	Cattle	Donkey	Horse	Other
(1-10) (11-20) (>30	**(1-10) (11-20) (>30)**	**(1-10) (11-20) (>30)**	**(1-5) (6-10) (>10)**	**(1-5) (6-10) (>10)**	
Residence	Farm/Cattle post	Nearest village	Jwaneng Township	Outside district	
Section C:	**Farm Details**				
How many persons live on cattlepost?					
How many persons work on cattlepost?	Full time:			Part time:	
Do you keep livestock in a fenced area?			Yes	No	
Vegetation type:		Can you give a percentage for each?			
Open grassland	Light Bush	Dense Bush	Very Dense Bush	don't know	
	10-35%	35-65%	65-100%		
What are the main problems encountered by livestock farmers? ***Rank importance: max 3***					
diseases		insufficient grazing		few extension visits	
drought		poor quality grazing		theft	
infertility		low yields		other…………..	
losses due to predators		unreliable market		other…………..	
Section D:	**Wildlife Details**				
How often do you see this predator? (5) every day,					
Predator	**Every few years to never (1)**	**Every few months to once a year (2)**	**Monthly (5)**	**Weekely (6)**	**Daily (5)**
Cheetah	1	2	3	4	5
Leopard	1	2	3	4	5
Brown Hyena	1	2	3	4	5
Wild dog	1	2	3	4	5
Caracal	1	2	3	4	5
Jackal	1	2	3	4	5

How many of each of these predators do you think live in and around the area in which you live?

Scale	1 to 5	6 to 10	More than 10
Cheetah			
Leopard			
Brown Hyena			
Wild dog			
Caracal			
Jackal			

On a scale of 1 (rare) to 5 (very common) Please detail which game species exist in the area:

species	status		Trends over past 10 years		
	absent, rare, common, v.common		increase, decrease, stable		
kudu					don't know
springbok					don't know
hartebeest					don't know
Duiker					don't know
Steenbok					don't know
warthog					don't know
hares					

Section E: Farm Management

What is your kraal design?

Cattle:	Wood & Wire/fence	Tree branches	Other (Specify)		
Distance from homestead		0-50m	50-100m	100-150m	>150m
Goats & sheep:	Wood & Wire/fence	Tree branches	Other (Specify)		
Distance from homestead		0-50m	50-100m	100-150m	>150m

Do you have a calving season?

All year	1st quarter	2nd quarter	3rd quarter	4th quarter

Do you have a lambing season?

All year	1st quarter	2nd quarter	3rd quarter	4th quarter

On a scale of 1-3 (3 as highest frequency), how often do you do the following during lambing or calving season:

bring calving animals closer to homestead?	1	2	3
check on livestock more often than before?	1	2	3
keep careful records?	1	2	3
kraal all livestock at night?	1	2	3
kraal young calves / kids?	1	2	3
use a maternity / calving kraal?	1	2	3
other?			

Do you have a herder with livestock? (Specify cattle/goats/sheep)	yes	no
How many do you have per number of livestock?		
Who are they (paid workers, children)?		
Are they effective?		

Do you have a dog with livestock? (Specify cattle/goats/sheep)	yes	no
What breed?		
How many do you have per number of livestock?		
Are they effective?		

Is there any other conflict mitigation method that you use not listed above? If yes specify.

Section H: Predation and conflicts					
Do you lose livestock to predators			yes	no	don't know
Classify the predators, according to level of problem:			**Rank**: 1: biggest problem; 8: least problem		
Jackal		Brown hyena			
Cheetah		Caracal			
Leopard		Wild dog		Other…………	
Have you lost livestock to predators in the last 12 months?			yes	no	don't know
Date	Animals killed	Predators	How it was identified	Time of day	Location
or season	or injured	responsible	(visual (by who), spoor	of incident	
	(no, spc,age, sex)	(number,spcs,age,sex)	carcass, heard calls)		
On a scale of 1(least often)-3 how often do you protect your livestock at night?					
	1. Cattle	2.Horses	3.Donkeys	4. Smallstock	Is it effective?
Kraal	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Herders	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Guard animals	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Calving season	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Other (explain)					
On a scale os 1(least often)-3 how often do you protect livestock from predators during the day?					
Kraal	1. Cattle	2.Horses	3.Donkeys	4. Small stock	Is it effective?
Herders	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Guard animals	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Lambing season	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	(1) (2) (3)	
Other (explain)					
Which of the following age classes of livestock are usually killed?					
Lamps/kids/calves/foals					
Sub adults					
Adults					
Other					
When are attacks most likely to occur?					
Day	Night	Inside kraal	Outside kraal	With Herder?	
				yes	no
Are losses to predators seasonal?			yes	no	don't know
Which season?					
Have you lost animals in the past 12 months, due to causes other than predators?				**Specify: number / species**	
If no numbers: rank importance: max 3					
Disease	Calving	Accidents	Starvation	Theft	Other……….
During your time in the area is the problem with predators:			increasing	decreasing	stable
Can you give reasons why?					
What do you do when you have a loss to a predator?					
Did you ever remove predators? How? When? (live trap, shoot, poison)				yes	no
Details:					don't know
Have you contacted National Park office for assistance?					don't know
Details?					

Section H:	**Attitudes**				
What do you think about sharing the land with predators?					don’t know
Benefit to farm	Like them	Dislike them	Kill on sight	Other…………	
Why?					
Do you think wildlife is a national resource to be protected?				yes	no
why?					
Who's responsibility do you think predator/livestock conflict belongs to?					don’t know
Farmers	Herders	Government	NGO's	Other…………	
What would be your suggestion as solution to the HWC issue ?					
Improve farm management		Translocate	Decrease numbers	Other…………	
Trophy hunting		Compensate	Tourism		
Do you think your antipredator methods are effective in the long term? Explain your answer					
Do you think all your livestock mortalities are due to predators?					
Yes	No				
Do you think all the above mentioned predators kill your livestock or do they mostly scavenge on already dead animals?					
Yes	No				
Contact address:					
Tel number:					
Ranking					
Precision			Co-operative attitude		
No wrong or doubtful info			Correct identification of predators and prey		
Consistency			Total	/5	(0; 0.5; 1)
Notes					